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METALS & ALLOYS

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Devoted to the Advancement of Scientific Metallurgy

Metallurgy of Valve, Fitting and Piping Materials
L. W. SPRING and H. W. MAACK

Dependence of Aviation on Metallurgy
J. B. JOHNSON

Effects of Silicon on the Properties of Brass
H. W. GOULD and K. W. RAY

Zinc as a Protective Coating against Corrosion Fatigue of Steel
WILBER E. HARVEY

The Solidus of the Iron-Carbon System
O. W. ELLIS

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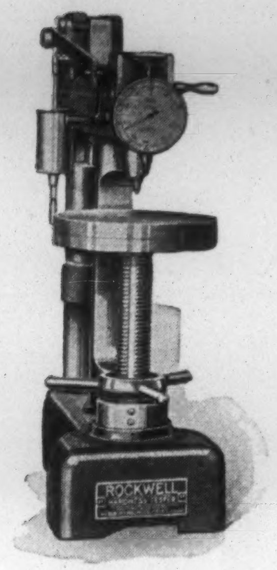

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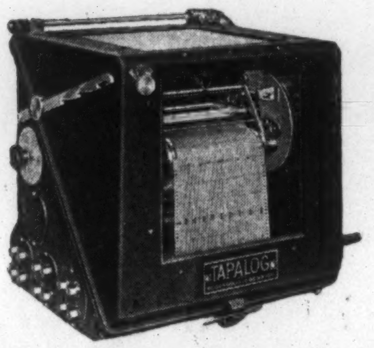

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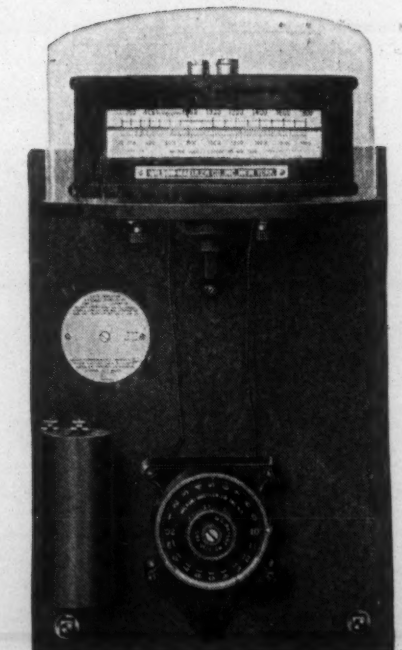

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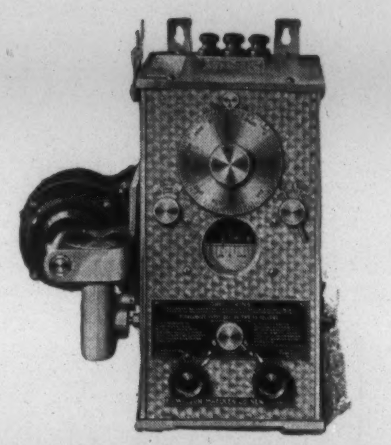

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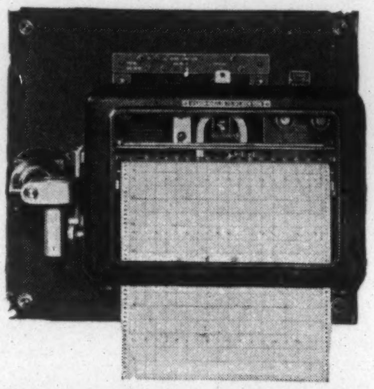

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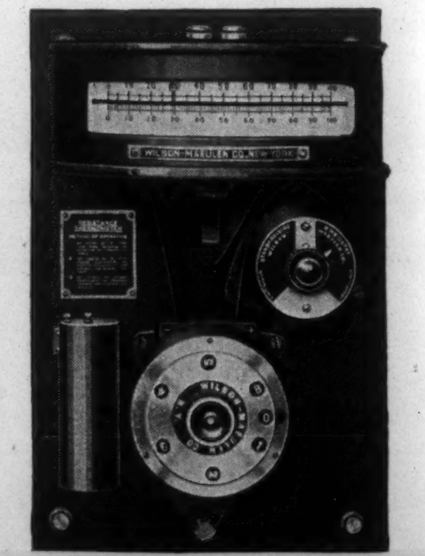

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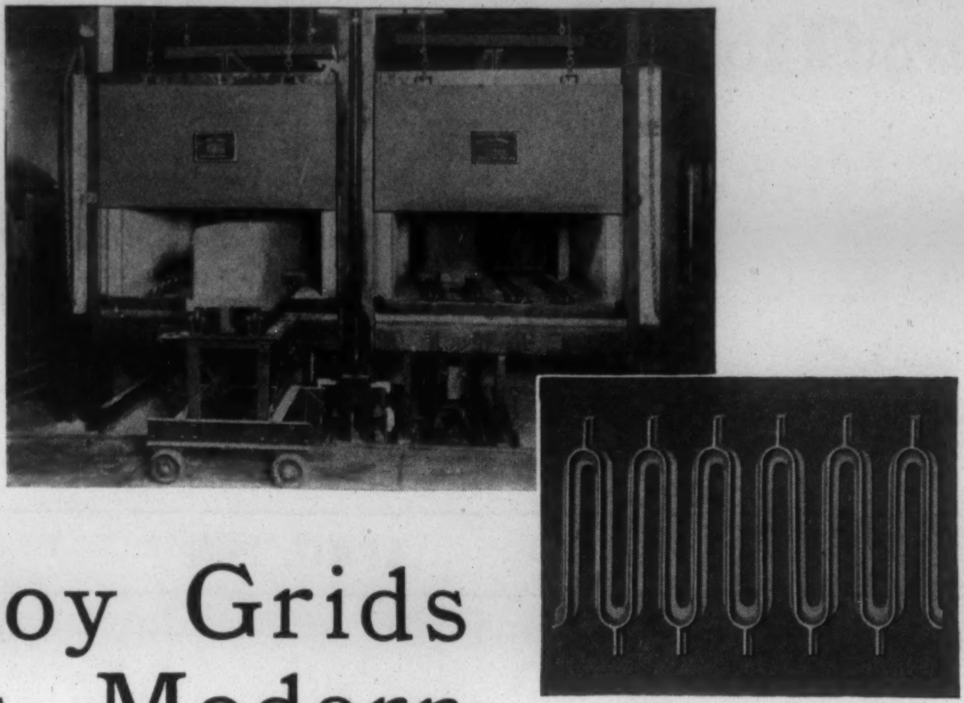

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PUBLISHER'S PAGE

Note— On this page the publishers will talk right straight to you each month. We will tell you how things are progressing with METALS & ALLOYS. *We will undoubtedly ask your advice on many points. We are publishing this paper not primarily to please ourselves but rather to serve you. And our office door is always open. You are invited to call.*

The steady growth of the subscription list of METALS & ALLOYS makes us feel sure that we were not mistaken when we assumed that there was a real need for a general technical metallurgical publication in America. Of course, we never had any very serious doubts that this was not the case because before starting publication we were assured by more than fifty most prominent metallurgists as well as by a large number of business executives in the metallurgical industries that there was a need for such a paper.

On the other hand it is very obvious to us that we have only made a small beginning toward developing the possibilities of usefulness of such a paper. At the present time we have just about 3000 subscribers. We have a prospect list of more than 30,000 people connected with metallurgical industries in one way or another who ought to be interested in METALS & ALLOYS.

Our present subscribers can help us by bringing the paper to the attention of their friends. We are always glad to send free sample copies to anyone likely to be interested. In helping us in this way you will also be helping yourself because the more subscribers we get the better paper we will be able to publish.

The research that is going on in metallurgical laboratories to-day will powerfully influence the plant practice of to-morrow. To illustrate what we mean: we need only to mention the present importance of nitriding; the constantly increasing industrial use of X-ray analysis; the rapid advance of chromium plating; and many other equally important recent advances. There is no better investment of time for any practical man in any way identified with metallurgical industry than to keep in touch with the latest developments of the science on which his business is based.

Hardly a day goes by that we don't get a letter from someone telling us that METALS & ALLOYS is the best metallurgical paper being published to-day. Our Abstract Service in particular is coming in for a lot of praise and we are glad of that, because we have gone to a lot of expense to develop it and feel that it is probably the most useful service that we can give to the metallurgical public.

The numerous compliments we are receiving, however, are not making us self-satisfied. We realize that probably there are lots of subscribers who are not so completely satisfied with the paper but who don't take the trouble to acquaint us with the fact.

Practically every case where we have received a suggestion as to some subject on which to publish articles or reviews we have been able to interest some competent authority in giving us an article along the lines desired.

Won't you let us have your suggestions as to subjects that are important to you and that you would like to have dealt with in our pages in future months? These suggestions will be given most careful consideration by our editors and we think in most instances we will be able to comply with your wishes. At any rate we will try.

Finally, we feel that many of our subscribers who may never have contributed previously to technical periodicals may have special knowledge of some practical phase of metallurgy that would be of interest to our readers. If so, let us have a chance to consider it for publication. We will welcome short notes and memoranda as well as long articles. Constructive criticism of articles that have already appeared is also always welcome.

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Editorial Comment

In this department I try to comment on metallurgical and allied matters that seem to me interesting and significant. The views expressed reflect my own personal attitude. Many of our readers will have ideas of their own on these subjects and are urged to contribute them in the form of letters which will gladly be published in succeeding issues.—H. W. Gillett, *Editorial Director.*

Confessions of Ignorance

The iron-carbon constitutional diagram is as fundamental in the work of the ferrous metallurgist as the Constitution is to the work of the Government. The Constitution has had various amendments, and opinions as to the worth of some of them are, to say the least, not unanimous.

Perfection, even in the Constitution, may not yet be fully attained, so it would be unreasonable to expect perfection in our most important and basic metallurgical equilibrium diagram, even though the diagram would express precise facts, if only we could be sure what the facts are.

According to the predilection of the individual professor, he teaches us some particular form of the iron-carbon diagram in college, or we take the diagram as it is given in some pet text-book. But the exact location, and even the shape, of some of the boundary lines differs materially from diagram to diagram depending on what data are used.

Scientific and technical journals primarily record what new things we know, or think we know, on the basis of the most recent observations.

Improved equipment and better technique presumably make the newer observations more reliable than the older ones, yet this is not always the case. Professor William Campbell recently wrote us as follows: "I remember thirty years ago working with Sir William Roberts-Austen in the basement of the Mint in London. They had built practically everything themselves. Even the microscope had been built up from parts of two or three different instruments. The famous recorder was built out of an old beer barrel. But the results have stood the test of time."

We must not be swayed too much by the date of a publication. It is worthwhile, every so often, to cast up accounts, and see where we really stand, considering both the old, time-honored findings and the newer ones. When we do, we often find conflicts of fact and of opinion.

It is sometimes very difficult to tell which of two conflicting ideas is the correct one. There is no easy guide to a choice, such as was given for the solution of some problems in the biological sciences by Carolyn Wells in her monograph on "How to Tell the Wildflowers from the Birds." We recall one part of this, which runs:

"Very few can tell the toucan from the pecan,
Here is a new plan,
To take the toucan from the tree
Requires immense agility,
While anyone can pluck with ease
The pecans from the pecan trees,
It's such an easy thing to do,
That even the toucan, he can, too."

The task is not so easy in metallurgy. There are two sides to many metallurgical questions, and when these are primarily of scientific interest and not obviously connected with practical use of the alloys in question, these moot problems may remain as enigmas for many years.

It is humiliating to the science of metallurgy to have to admit that there is so much about the iron-carbon diagram that is unknown. Yet an honest confession of ignorance, and a clear stating of the moot problems may encourage the work that is necessary to clean up the problems.

Hence, some of the moot points relating to the iron-carbon diagram will be discussed in Metals & Alloys through correlated abstracts, and notes by metallurgists who have been intrigued by the lack of precise information, and of agreement in respect to various parts of the diagram. The first of these is by O. W. Ellis, in this issue. Others will follow in subsequent issues.

Research, the Parent of Specifications

Changes in metallurgical products and processes, due to research and development, are ultimately reflected in purchase specifications such as those of the American Society for Testing Materials. Work is going on in that society, through committees, sub-committees, and sub-sub-committees (whose designations run the gamut of the Arabic and Roman numerals), and often in cooperation with other technical societies, on various projects which sooner or later will result in new specifications. In this category come the work on drafting a specification for Intermediate Manganese rails; one for heat-treated helical springs; consideration of increased tensile requirements for structural steel, and the possible restriction of the use of Bessemer steel in this grade; study leading toward revision of specifications for carbon and alloy steel forgings; work on a specification for open-hearth pure iron boiler plate; a pending revision of the definition for wrought iron avoiding reference to the process of manufacture; work looking toward a standard impact test for cast iron; complete revision of the series of specifications for sand cast light alloys of aluminum to make them represent modern practice.

In many of these projects, one can recall the article or the symposium in which research results were presented to show that there is a better or a cheaper way to make a product; that a new and better product can be made; or how to perform a given test in a more precise or a more rapid fashion.

Some very comprehensive projects, such as the atmospheric corrosion exposure test on galvanized materials, non-ferrous alloys, etc.; on the high temperature properties of metals; on electrical resistor alloys; and on alloys for die castings, will require years more of cooperative research endeavor before the facts will come into fruition as specifications.

The mechanism by which official specifications are made necessarily operates slowly, and individual consumers who keep in touch with the trend of the results of metallurgical research may and should anticipate in their own purchase specifications those advances which others will come to, or be forced to, later. Producers who are ahead of the procession as a result of their own research and their contact with that of others can also score by being able to supply super-specification materials before everybody else makes them too.

Such unofficial specifications are sometimes looked at askance by those who are wrapped up in the making of official specifications. On the other hand, some people who are interested in making super-specification materials rail at the official specifications because of their failure to reflect the latest research advances. All these specifications, official and unofficial, as well as the materials better than present specifications, are quite legitimate offspring of research.

If the research laboratories, on whose results are based the advances that later accrue to the benefit of the general public in better and cheaper goods, should fail to keep up the flow of results, or if those results were not made available through the medium of technical and scientific transactions and journals, the public would continue to use in the future about what it is using now instead of something better.

Specification-making is one of the steps in the translation of scientific research into more desirable and more salable goods.

Metallurgy of Valve, Fitting and Piping Materials

Some Fundamentals

By L. W. Spring[1] and H. W. Maack[2]

> *Old Doc Munyon used to make a patent medicine that was good for what ailed you. But there is no panacea for the various corrosion problems of modern industry. It is necessary to let the punishment fit the crime.*
>
> *The selection of a metal which shall best meet the varied requirements of the case is a real task confronting the metallurgist and the purchasing agent.*
>
> *Here is a clear statement of the fundamentals involved in the selection of materials to meet a wide variety of severe corrosive conditions.*
>
> *While complete satisfaction may not yet be attainable in all cases, the progress made so far is a credit to the metallurgical profession.*

It is well known, of course, that piping and fittings are largely used for the carrying of water, gas, oil, steam, etc., while valves and cocks are the usual means for controlling their flow and delivery.

Early service for these fluids was at comparatively low pressures and temperatures. Speaking of the steam industry, such, up to 25 years ago, were seldom more than 100 or 200 lbs./in.^{2} with 300–400° F. temp. Shortly after the first of the present century, higher pressures with accompanying higher temperatures came in, and even an additional 100° F. temp. in the way of superheat in power and lighting plants. During the past fifteen years steam pressures have risen to 600 lbs. and, in several instances, 1500 lbs./in.^{2} pressure is being used with total temperature of approximately 750° F.

Due largely to the automobile and its demand for gasoline, the oil refining industry has had a huge development during the past 10 years, the greatest part of it during the past five years. Here, due to a number of reasons, development has not been as leisurely as in the steam industry and already 600, 1000 and 1400 lb. pressures are more or less general, while 900° F. temp. for the cracking of heavier oils into gasolines is very largely used and temperatures often run even higher.

Some chemical industries, too, are using correspondingly high pressures and temperatures.

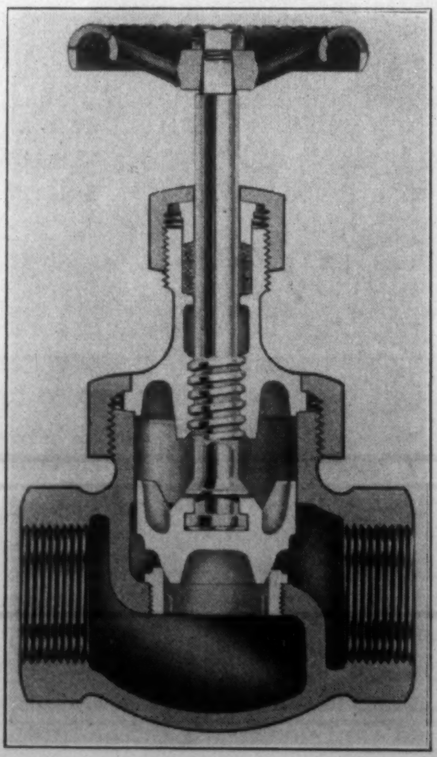


Fig. 1—Globe Valve Section Showing Seat Ring, and Disc on Bottom of Valve Stem

Early Materials

At the first of this century, the usual material for boilers and piping was steel, just as it is now, except that we have since come to more careful manufacture and inspection and toward a stronger material with higher carbon, sometimes with alloys, and, to a considerable extent, from welded steel pipe to seamless steel tubing.

For cold water, air and gas, steel, wrought iron and brass pipe continue to be used, usually with brass valves, the latter for resistance to corrosion and consequent leakage past the "seat."

It will be recognized that the life of a valve is its seat. Such, in a check or globe valve usually consists of a disc and a ring, and in a gate valve of a disc and two sets of rings, one set usually screwed into the body, the other rolled or otherwise fastened into the wedge-shaped disc. These combinations must be so accurately finished and adjusted during manufacture that with the valve closed there is not the slightest passage for fluid. Any tool mark or even a scratch made by a piece of sand, grit or pipe scale getting caught between and marring the valve seats may be sufficient to cause the valve to leak.

Up to 20 years ago the great majority of larger valves for water service, gas and for power house steam service, were of cast iron, with seating parts of brass or the harder tin-copper bronze. These were quite serviceable even up to 450° F. on saturated steam, but, with the advent of superheated steam and higher temperatures they did not suffice. It was found that cast iron sometimes "grew" or increased in volume and the valve or fitting in length, due apparently to oxidation or some internal incipient decomposition caused by the higher temperatures. Too, it came to be felt that cast iron was too brittle and fragile a metal to use in the increasing sizes and under the increased pressures that were becoming necessary. When brass or the tin-copper bronze rings were used at the higher temperatures it was found that they often became loose although originally screwed perfectly tight into iron or steel valve bodies. This was traced to the fact that with coefficient of expansion of approximately 0.0000100″ per ° F., the thin, weaker brass rings could not expand normally against the much heavier and stronger cast iron or steel body which had corresponding coefficient of expansion of only 0.0000065″, hence the brass rings were compressed, or rather compressed themselves, and later were found to be loose upon cooling. Definite laboratory-type tests of such sections and metals, proved this to be the case. For the above reasons steel castings replaced the cast iron, and nickel or nickel bronze rings, such as Monel Metal, replaced quite satisfactorily the brass rings. These nickel alloys, too, were resistive to ordinary corrosive

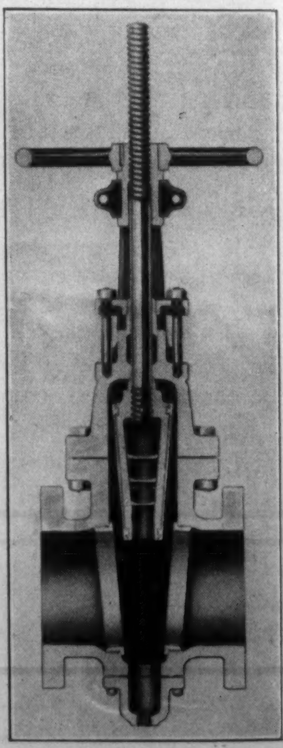


Fig. 2—Gate Valve Showing the Two Screwed-In Body Rings and the Two Disc Rings Locked by Prongs into the Disc (See Fig. 3 Insert for Detail Ring Fastenings.)

---

[1] Chief Chemist & Metallurgist, Crane Co.

[2] Asst. Chief Chemist & Metallurgist, Crane Co.

influences, and, having a coefficient of expansion of about 0.0000070" per ° F. there was little or no trouble through seats coming loose.

A Demand from the Oil Refiner

When the great demand for gasoline came about ten years ago, the oil refineries were taxed to their utmost and an era of intensive building of new and larger oil stills using higher pressures began. Up to that time regular steam valves for the first or distillation process had been quite satisfactory. In the rush of this new intensive development, their chemists, engineers and operating men were so busy with the new construction and the larger scale processes that they had little time for their new subject (to them) of metallurgy. The main thing was to get enough stills, piping, valves and equipment ordered and to build so that they could get to making more gasoline. So, with the older, low pressure, low temperature processes and their usual crude oils still in mind, the best valve then made for steam naturally seemed to be the best valve for their stills and vapor lines. Neither did the valve manufacturer know better. But the effect of the much higher temperatures and pressures and the organic sulphur vapors of some of the new "crudes" from the hundreds of newly drilled oil wells over the country soon were found to be disastrous to the seating metals used in the valves. Some valves were found with seat and disc rings entirely dissolved out in much less than a year.

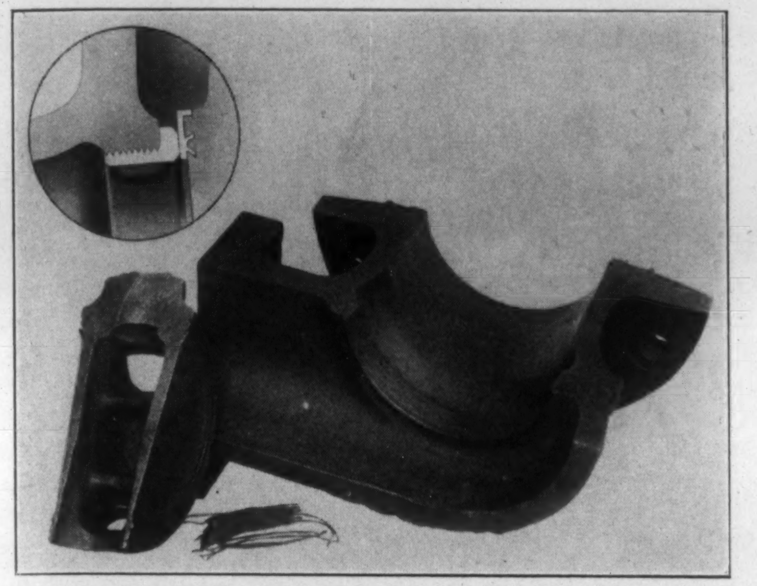


Fig. 3—Parts of Used Gate Valve from Which Both Body and Disc Rings of Nickel Copper Alloy Were Dissolved During the Manufacture of Gasoline, and Scraps of Original Rings Dug Out from Bottoms of Threads. Insert Shows Ring Assembly at about Twice the Scale of Main Figure

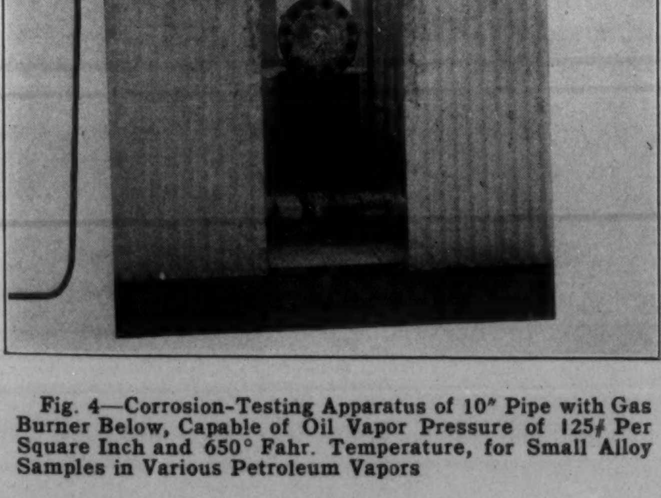


Fig. 4—Corrosion-Testing Apparatus of 10" Pipe with Gas Burner Below, Capable of Oil Vapor Pressure of 125# Per Square Inch and 650° Fahr. Temperature, for Small Alloy Samples in Various Petroleum Vapors

Much study and experimenting was done by metallurgists of the manufacturers, considerable also by the oil refiners themselves and by the two working in conjunction. The newly-arrived stainless iron with 12% or more of chromium soon was found to have the requisite corrosion resistance toward the gaseous sulphur compounds. Such, since, has been largely used for valve seats. Other high chrome iron alloys with and without nickel were found to be excellent also, though some of the latter were difficult to fabricate.

Some of the Complications in Prescribing Satisfactory Metals

However, in what are called the "run down" lines in a later part of the refining process, the slight hydrochloric acid content of the gasoline makes the plain chrome iron inadvisable, so other metal, usually acid bronze, has to be used. While for strong sulphuric acid, steel and cast iron are quite satisfactory (strong sulphuric, often called oil of vitriol, or "oleum" (fuming), usually being shipped in steel tank cars), the treatment of some of the light petroleum products after distillation includes the use of both strong and weak sulphuric acid as well as alkali. This is done in what is known as an "agitator." In this large, funnel-shaped steel tank, the oil and sulphuric acid are "blown" with air to mix them thoroughly, by which impurities are destroyed by the acid, which then is allowed to settle and is drawn off through a valve at the bottom. Most of the remaining acid is then washed out by rinsing the oil with water, the last traces are killed by agitation with weak soda solution, and finally with water again, each being settled out and drained in turn. While several metals are satisfactory for acid and others are satisfactory for alkali, very few are satisfactory for both alkali and acid, the latter both strong and weak. Furthermore, steel and cast iron, while satisfactory for strong sulphuric acid, are quite rapidly dissolved by weak sulphuric acid. The washing of the oil with the use of water after strong sulphuric acid, of course, forms weak sulphuric acid. While the steel tank naturally is cut and has only limited life, the valve, through which the strong sulphuric acid, weak sulphuric acid, alkali and the last wash waters are drawn from the agitator, is a critical part of the apparatus. Some are of bronze with high lead content while others are pure copper-tin bronze with about 10% tin. A later valve, which has found considerable favor, is of a nickel copper alloy with a base of approximately one-fourth nickel and three-fourths copper.

Thus, it is seen that often there really are two main divisions in such problems—one the material for the heavy pipe, valve body, boiler and oil-still shell on which the allowable limit of corrosion, mainly, is eventual weakness through general or local thinning, or failure due to holes dissolved in the walls; the other, the much less or even minute corrosion sufficient to disable and cause a valve to cease to be

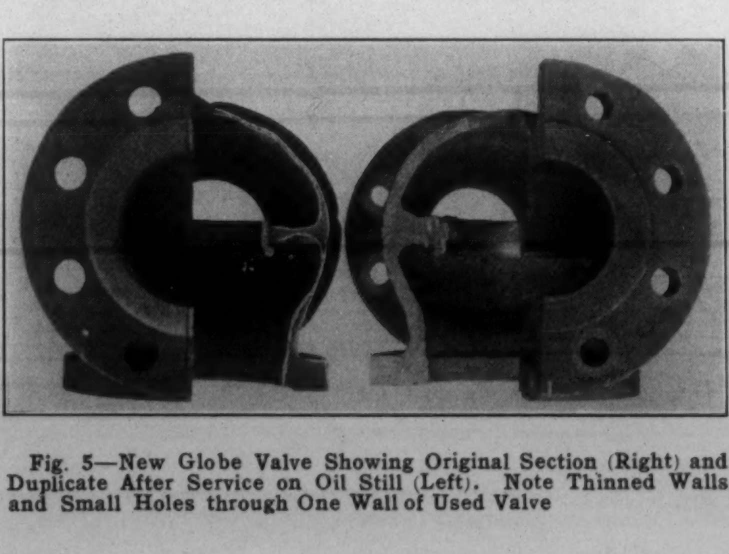


Fig. 5—New Globe Valve Showing Original Section (Right) and Duplicate After Service on Oil Still (Left). Note Thinned Walls and Small Holes through One Wall of Used Valve

"tight." Five years ago some of the oil refiners after measurement figured that their drum-type still shells thinned $^{1}/_{6}''$ per year and thereby estimated for how many years they would be safe. On the other hand, a valve is tight and really useful only as long as its seats are "tight" and it may require only 0.01" corrosion or a minute scratch on the seat to make it comparatively useless. The leaking of valves because of faulty or damaged seats is of much consequence to the user.

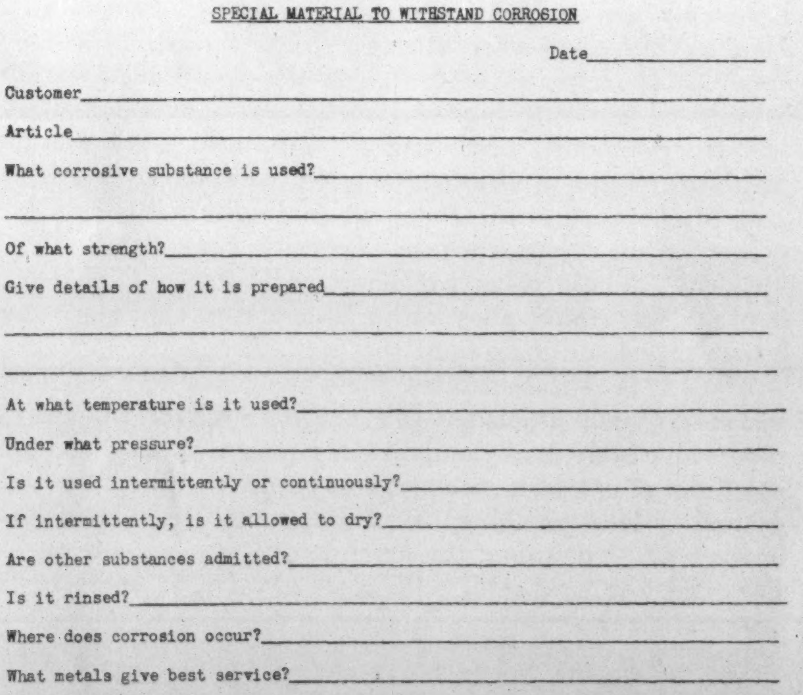
A Few of the Requirements of a Proper Seating Metal

From the metallurgist's standpoint, the question of seating metals presents, then, a considerable problem, some of the many characteristics necessary for a proper one being:

Non-corrosiveness
Proper coefficient of expansion
Forging or casting quality
Machinability
Density and smooth texture
Proper strength and ductility
Hardness sufficient to withstand scratching
Non-galling or seizing quality
Reasonable cost.

New metals and alloys, satisfactory from the purely non-corrosive standpoint, ofttimes are available for which the fabricating cost is prohibitive. Some do not cast satisfactorily, some cannot be rolled or forged or are so tough that machining is not possible from a production standpoint. The best material may be so costly from the standpoint of time and labor to fashion it that a somewhat shorter lived but reasonably priced material really may be a better choice, when cost of shut down and labor in plant to replace a leaky valve is not excessive.

It is fortunate that the seating parts of the valve are of small weight comparatively, for fairly costly metals can be used, if necessary, without prohibitive expense. For example, silver is used in the seating of some valves for chlorine, because of its excellent service on moist chlorine gas and the limited amount of the metal required.



SPECIAL MATERIAL TO WITHSTAND CORROSION

Date ____________

Customer ____________

Article ____________

What corrosive substance is used? ____________

Of what strength? ____________

Give details of how it is prepared ____________

At what temperature is it used? ____________

Under what pressure? ____________

Is it used intermittently or continuously? ____________

If intermittently, is it allowed to dry? ____________

Are other substances admitted? ____________

Is it rinsed? ____________

Where does corrosion occur? ____________

What metals give best service? ____________

What packings give best service? ____________

What metals give poorest service? ____________

What packings give poorest service? ____________

Additional information ____________

IF POSSIBLE, SUBMIT SAMPLE SHOWING CORROSIVE ACTION!

Fig. 6—Corrosion Blank. Customers Give Information Concerning Deleterious Chemicals to Assist in Providing Proper Metals

Valves for Steam Service

As stated, high nickel copper bronzes of 50% or more of nickel were used in high grade valves for steam service for many years. These are non-corrosive under ordinary circumstances, are strong, have ductility enough that they can be "rolled in" or fastened into valve discs in other ways than by threading and screwing them in, have a satisfactory coefficient of expansion, can be forged and cast satisfactorily, have fair machinability, and some of them are readily available in good quantity, shapes and sizes. Such were quite satisfactory until the higher pressures and temperatures made service conditions extremely severe. They still are considerably used but have the disability of "seizing" and roughening when two surfaces of the metal slide against each other under heavy pressure. This "seizing" is a real disability since a torn and leaky seat starts "wire drawing" which brings on yet more serious leakage if, perchance, it was not serious enough already. The pressure on the seating surface under 900 lbs. load on one side of the disc of a 16" gate valve, for instance, is estimated to be approximately 5000 lbs./in.^{2}. Materials which will stand rubbing together under such pressures must have certain characteristics, which are not yet definitely understood, and it is admitted that the perfect seating metal for extremely severe service over various temperature ranges may not yet have been found. Cast iron for the lower temperatures was good because of its more or less self lubricating seat, due to content of graphite. The copper-tin bronzes are fairly good from the standpoint of "seizing" but, as previously stated, they have the disability of a high coefficient of expansion. The addition of tin or other hardening element to the copper-nickel bronzes helps materially and some of these are giving fair satisfaction in present-day service.

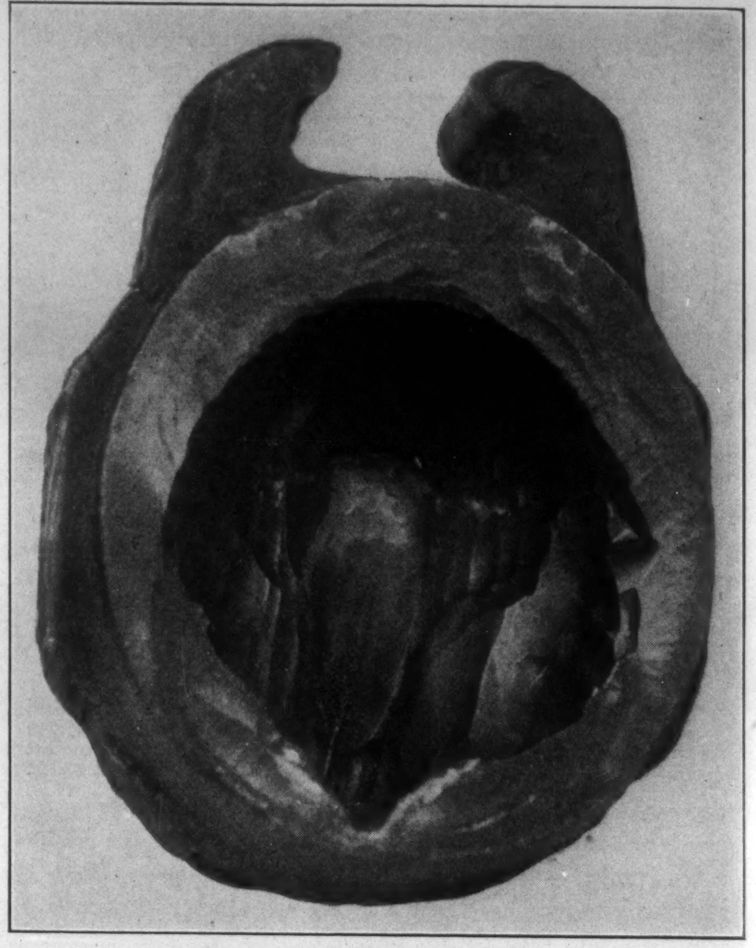


Fig. 7—Valve Disc Showing How High-Velocity Impinging Fluid Cuts into (or through) Metal

Nitralloy—A New Seating Metal

How much of a factor in resisting seizing and scoring, "hardness" of the material is, is not definitely known, though, other things being equal, hardness is quite a factor. The extremely hard case-hardened steel with 700 Brinell makes a good seating metal so far as this one matter of "seizing" or tearing is concerned, but it is not non-corrosive, and a valve seat which rusts under ordinary conditions of moisture, of course, is impractical. A comparatively new seating metal, Nitralloy, has appeared. Nitralloy is a forgeable steel containing small proportions of chemical elements which cause the surface of the alloy to become glass hard when heated to 900 or 1000° F. for a period of hours in a stream of dry ammonia gas. This case or coating which usually is from ten thousandths to thirty thousandths inches thick, depending upon the length of "nitriding" treatment, is non-corrosive under ordinary circumstances, does not seize or tear and has the peculiar advantage of becoming smoother as it wears. Nitralloy is giving very satisfactory results in steam service. It also is resistive to sulphur vapors in oil cracking.

Some of the Hazards of Modern Industry

On cracking stills in the oil refinery, gasoline nowadays is given off as vapor from the pipe still at 900 or 1000° F. A person standing forty feet in the air on one of these high powered monsters, feeling the framework under him tremble under pressures of 600 lbs. or more per sq. in. as the gasoline vapors rush through, realizes with more keenness than ever before what would happen should some part of the apparatus spring a leak. Gasoline fumes at such temperature (900° F. is a low, red heat) ignite spontaneously when they strike the air. That there are not more terrific explosions and fires in the oil refineries in these days of huge demand for gasoline is a tribute to the engineering skill of designers and builders and the watchfulness and loyalty of the men who operate these refineries. Nor is it only in the oil refinery that hazard lies. The breaking of a nine or sixteen inch steam pipe carrying live steam under even 600 lbs. pressure from several connected boilers in a modern power plant, would be highly disastrous even with the automatic stop-check valve cutting off its steam supply.

General Corrosion and Contamination

But, of course, in many industries even the two factors, tightness and length of time the pipe and valve wall will last before being corroded through, are not the proper criteria, for sometimes solution of and contamination by a little of the container metal may spoil a later chemical reaction, or the color of a dye, or render a food product unpleasant of taste or even make it poisonous. No copper, or iron is allowable in pipe or valves for handling of photographic developer, pure nickel being required, while alloys with lead or zinc over $^1/_2$% are barred for fruit juices, catsups and some other food products. Pure tin, nickel, Monel Metal, aluminum and the new chrome-nickel-iron alloys are best for foods, fruit juices, etc., though copper kettles and the pure tin-copper bronzes still are used.

Nitric acid is much used in the manufacture of gun cotton and explosives. The chrome-iron alloys such as stainless steel, straight 18% or 22–28% chrome, the new 18% chromium-8% nickel, and some others of the chrome-base alloys are very serviceable with nitric acid. Aluminum also is much used for nitric acid service.

Consumption of strong sulphuric acid of 1.84 specific gravity (66° Baumé) often is called the barometer of the activity of the chemical industry just as the tonnage of steel is considered a general business barometer. This acid is shipped in steel tank cars and handled through "all iron" or steel valves, i. e., body and seats of cast iron or steel, the seats usually "cast integral" with the body. However, as stated, this will not do for more dilute sulfuric acid, even for that of 1.70 specific gravity (60° Baumé), which has only about 20% of dilution. For the weaker sulphuric acid, an acid bronze of pure copper and tin or a leaded copper alloy body with seats of the same materials is used. Lead pans and lead-lined equipment are much used for manufacture and constant handling of sulfuric acid.

"Acid mine water" usually owes its acidity to sulphuric acid resulting from oxidation of sulphur compounds from the soil or rocks, such as iron pyrites ("Fool's gold"), the yellow metallic material one often sees in lumps of coal. Being very weak acids these rapidly eat out pipe, fittings and valves made of steel or cast iron. Every valve manufacturer has seen returned cast iron valves of practically normal appearance externally, which could be whittled with a jackknife. The weak acid leaches out the iron from the alloy leaving the silica-graphite structure of the valve body intact. Such corroded material whittles much like the graphite "lead" of a pencil.

Duriron is a special cast iron containing 12–14% silicon which is quite satisfactory for acid service in general but its fragility and low strength limit its use largely to evaporating pans, pumps, piping and acid handling equipment where low strength is not a disadvantage.

One of the Promising New Metals

In the sulphite paper industry, large digesters usually have had steel shells lined with sheet lead with acid-proof bricks inside. Copper-tin bronze or leaded copper-tin bronze valves and fittings have been usual for many years.

The new alloy, containing 18% chromium and 8% nickel now is claimed to give very satisfactory results even without any lining at all. This alloy, with or without molybdenum or other addition, has not yet come into its own, however, due to its comparatively high cost and the considerable difficulties encountered in its manufacture. While tubing and rolled products of this alloy are available, the metal is somewhat difficult to cast into valves and fittings and, in particular, the machining of the alloy is difficult on account of its toughness. Valves and fittings are being made of it, however, difficulties in casting and machining being gradually overcome. This same alloy also offers considerable advantage to the oil refinery and it is only a matter of time, seemingly, when it will be more largely used.

No attempt need be made to extend the list or go into the many ramifications encountered in prescribing valve, fitting and piping materials for corrosion, this article being merely for illustration of the general points at issue.

A Rapidly Growing Chemical Industry Will Bring Further Demand

This country (and other countries for that matter) may be said to be just beginning its chemical industry. When one considers the immense number of chemicals and chemical combinations used and new compounds to come, with the knowledge also that sometimes it is not one of the main chemicals intentionally present but perhaps a trace of an unsuspected impurity which does the corroding and causes the damage, a faint idea can be gleaned of the demand on the chemist, metallurgist and manufacturer of metals, and the fabricator of metallic products of the sort.

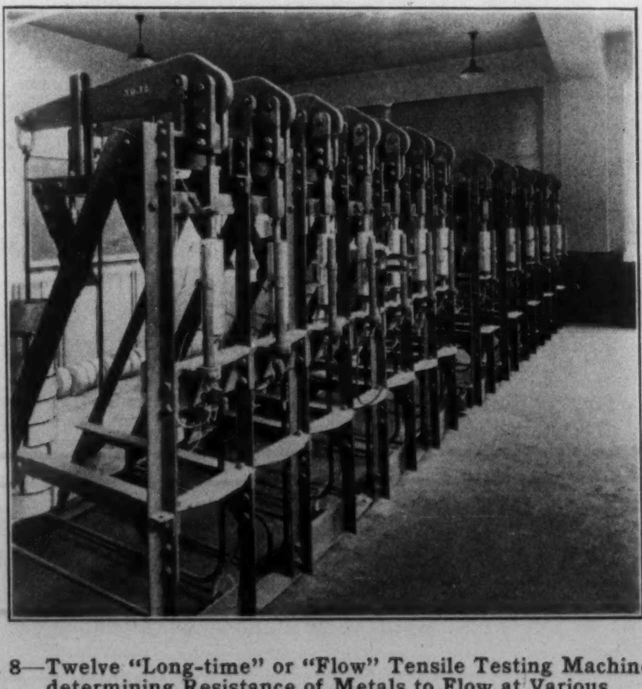


Fig. 8—Twelve "Long-time" or "Flow" Tensile Testing Machines for determining Resistance of Metals to Flow at Various Temperatures

Dependence of Aviation on Metallurgy[1]

By J. B. Johnson*

> ***Necessity is the mother of invention. Many of the advances in metallurgy have resulted from the demands of the user for better and more dependable alloys.***
>
> ***In the early days, naval requirements for projectiles and armor brought improvements in alloy steels. Then the automobile called for further metallurgical refinements. Now aircraft makers are demanding still better materials all along the line,—steels, bearing metals and light alloys.***
>
> ***The exacting requirements of the aircraft industry are being fairly well met, and with continued research will be still better met. Better materials will be available for general use as a result of the efforts put forth to solve aircraft problems. Quality alloys, once available, find use in wider fields than the one that called them forth.***
>
> ***Hence, beside the romance attached to all aircraft matters, articles like this on aircraft problems forecast the type of materials, and the methods of inspection and testing likely to be quite generally required in the future.***

Progress in any branch of engineering is closely related to the discovery or improvement of materials and methods of fabrication. Aeronautical engineering is no exception. In fact, it tends to stimulate investigation and research in these fields. The fact that a saving in the structural weight of a given design will permit increased pay load is a simple application of the law of gravity but the problems of maintenance and safety also influence the choice of material.

If it would be possible to construct a motorless airplane in which there is no metal, metallurgical processes would be relegated to their application in the manufacture of tools for the fabrication of the wood, textile and rubber parts. In the case of modern high-powered airplanes, however, materials are, to a large extent, a product of the metallurgist. Metals are favored on account of homogeneity, durability, permanency of volume and form under extreme atmospheric conditions, rigidity and resiliency. Metal does not always give the lightest weight for economical design. Wing ribs can be manufactured of plywood with sufficient strength to meet the load factor and lighter than the best metal ribs, although actually, the metal ribs might have a better strength-weight ratio but with an excess strength which is out of proportion to the rest of the design. The sheet metal which is available for wing covering has certain advantages but on a weight basis cannot equal doped fabric. The wood and fabric wing and metal fuselage for the light two place and small cabin airplane is still the most efficient type of construction judged solely on a strength-weight basis. Since the wing group represents almost half of the structural weight (Table I) for this type of airplane, it is apparent that there is a large field for research. In the case of larger airplanes, the type of construction is less standardized. Some designers prefer welded and heat treated steel wing beams (Fig. 1) with aluminum alloy ribs and fabric covering; others have a preference for riveted beams, ribs and covering of aluminum alloy.

Table I—Percentage Weight of Major Assemblies to Total Weight of Structure Without Engine

Type of Airplane	Wing Group	Tail Group	Fuselage	Landing Chassis
Two seater biplane	46	8	30	16
Type of construction	Wood fabric	Welded steel fabric	Welded steel fabric	Welded steel
Transport monoplane	37	4	43	16
Type of construction	Riveted aluminum alloy	Riveted aluminum alloy	Riveted aluminum alloy and welded steel	Welded steel

The increase in the use of metal indicates that the aeronautical engineer does not consider the strength-weight ratio as the sole criterion for the acceptability of the material.

Every improvement in metallurgical practice, which increases the homogeneity of the metal, affects aircraft performance. The formulas used in design are derived on the assumption that the material is uniform and homogeneous. If this is not the case, the margin of safety of the aircraft part may be seriously reduced. Specifications for aeronautical materials have been criticized for requiring too many specimens for the inspection tests but these tests are not only to identify the material but to determine its uniformity.

Uniform chemical analyses and physical properties are not the sole requirements for homogeneity; surface finish, internal defects, dimensional tolerances, eccentricity and grain size are other factors. The chemical analyses of practically all steels used in airplane and engine construction are identical with automotive standards as established by the Society of Automotive Engineers. The tabulation given in Table II (pages 452–453) does not give all the metals which are used but is representative of general practice.

It is noticeable that in airplane construction, practically no use is made of the screw machine steels containing high sulphur and phosphorous. There have been several failures of parts manufactured from such material especially when subjected to vibration. Aircraft nuts are made of S.A.E. 1025 steel on account of the uniform quality and higher strength.

The use of the modified S.A.E. 3140 chromium-nickel steel for crankshafts and connecting rods is quite general.

Gears are manufactured from forged gear blanks of either carburized or oil hardened steel. An examination of service statistics does not indicate superiority for either type.

The chemical composition of the non-ferrous metals, especially the alloys of aluminum and magnesium must be controlled within fairly narrow limits in order to obtain maximum physical properties and corrosion resistance. These metals are generally used in the form of polynary alloys and the reactions between the several elements are complex. A variation in the proportion of iron to silicon in the sand cast, heat treated aluminum-copper-silicon alloy will change the tensile strength and elongation more than 25%. The proportions of nickel and magnesium in the piston alloy have a great influence on porosity and pinholing. The small amount of manganese in the magnesium-aluminum alloy has a marked effect on the non-corrodibility of the alloy.

The physical properties of airplane materials are, in general, the maximum which can be obtained. In order to obtain the balance between strength and ductility it is necessary to exercise close metallurgical control over the methods of manufacture and heat treatment. The requirements specified for sheets and tubes cannot be obtained in the

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* Chief of Materials Branch, Material Division Air Corps, War Dept., Wright Field, Dayton, O.

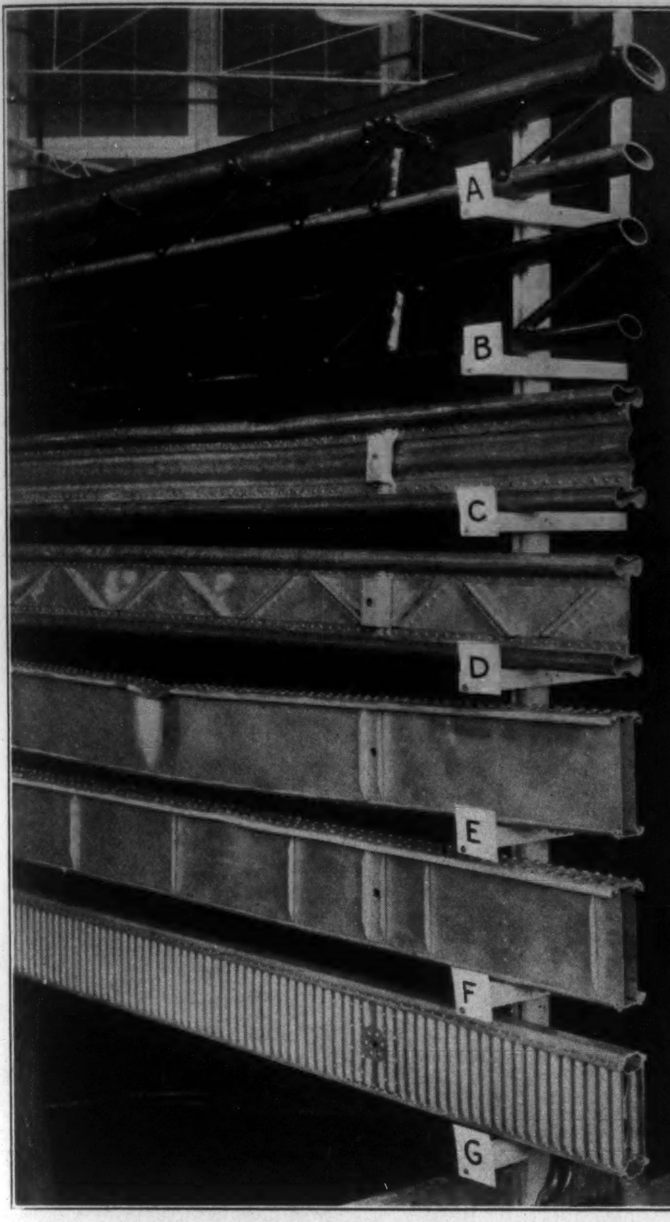

Fig. 1—Experimental Types of Wing Beams

A. Duralumin flanges—welded chrome-molybdenum steel webs B. Welded chrome-molybdenum steel heat treated to 150,000 lbs./in.². C-G. Heat treated, riveted duralumin.

ordinary commercial grades. The design problems of airplane structures are similar to those of other engineering structures with the added requirement of low weight. The fuselage and wing cellule of an airplane are frame works of tension and compression members. The compression loads are usually the critical ones, and, therefore, it is important that the material have a uniform modulus of elasticity for long columns and a high yield point in compression for short columns. The importance of the modulus of elasticity is rarely appreciated by the metallurgist. It is generally assumed that it is a constant quantity. This is not the case and cold drawn carbon steel tubing may have a modulus as low as 20,000,000 lbs./in.², whereas the value used in design is 28,000,000. One of the advantages of a medium carbon (S.A.E. 1025) or a chrome-molybdenum tube is the greater uniformity in modulus since the physical properties are obtained by thermal treatment and not by cold work as is often the case with low carbon tubing. A transverse test is a very satisfactory non-destructive test for determining the strength of tubing. The deflection is a function of both the modulus and the stress in the outer fiber. The simple machine shown in Fig. 2 has been used with success for the routine inspection of tubing.

The yield point in tension is not always equal to that in compression. This was demonstrated recently by a series of tests on aluminum alloy tubes. The tubes have been heat treated and then stretched in order to develop a higher tensile yield point. The increase in the tensile yield was made at the expense of the yield point in compression as indicated by the following tabulation:

Heat Treated Duralumin Tubing

		Yield Point	
	Tensile Strength	Tension	Compression
Normal	60,000	35,000	32,000
Stretched	65,000	47,000	31,000

The yield point was taken from the stress-strain curve at the point where the slope was 50% greater than the modulus slope. The material was not improved for use in aircraft construction.

Bending properties are important especially for sheets as the bend test is a good indication of the tendency to crack on the outside of the bend after the fabrication of a fitting, which under alternating stresses, rapidly produces failure. The combination of tensile and bend test has been found preferable to any ductility test made by cupping. The bend test is also a useful and practical test for stream line wire. It eliminates excessively brittle material and tie rods which have been improperly cold rolled so that an overstrained skin is developed.

The torsional characteristics of a metal are closely related to the tensile properties. Tubes are often used as torsional members but after once determining the relation between the tensile and torsional strength, it can be safely assumed that this relationship remains the same. Torsion tests are required on spring wire as a means of checking the ductility and also the uniformity of heat treatment.

Notched bar impact tests are required by some manufacturers as a check on the quality and heat treatment of ferrous forgings. The impact value is influenced to some extent by the tensile strength and ductility.

The properties of aluminum and magnesium alloy forgings and castings are determined by tensile and hardness tests and visual examinations of fracture. A propeller forging has a coupon attached which is notched and fractured and also machined into a tensile specimen. The examination of the fracture is important as the test specimens are cut with the axis longitudinally and many of the defects are parallel to this axis and their influence could only be determined by a test cut parallel to the minor axis of the section which is impractical on account of the small dimension. Foreign inclusions and fibrous laminated structures cause rejection.

Brinell and Rockwell hardness is used successfully for determining the uniformity of material. Tests are made on each individual piece. In the case of non-ferrous metals a minimum limit is generally given; for ferrous parts a maximum and minimum limit with a usual range of 40 points on the Brinell or 5 points on the Rockwell C scale. Variations of from 10 to 20 points Brinell on different parts of a crank shaft are quite common but there are no data on aircraft engine forgings which indicate that they have any effect on the serviceability of the forging. Such variations in hardness are not accompanied by differences in microscopic structure.

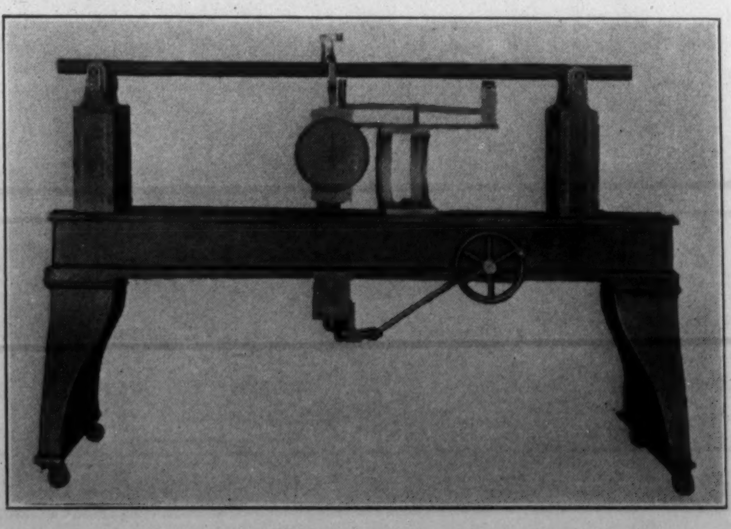

Fig. 2—Transverse Bending Machine for Non-Destructive Test of Tubing

Table II—Metals Used in Aircraft Construction

Ferrous

Designation	Chemical Analysis Carbon	Nickel	Chromium		Form	Physical Properties Tensile Strength Lbs./in.^{2}	Yield Point	Elong. 2″ Percent	Other Tests	Uses
1015	0.10–0.20	....	....		Bar	.....	....	..	......	Carburizing
					Sheet	38,000	20,000	35	Bend	Deep drawing—tanks (tinned)
					Strip	45,000	25,000	22	Bend	Wire wheel rims
					Bar[1]	55,000	36,000	22	Bend	Misc. forgings; screw machine parts; nuts[2]
1020	0.15–0.25	....	....		Sheet[1]	55,000	36,000	22	Bend	Fittings
1025	0.20–0.30	....	....		Tube[1]	55,000	36,000	22	Crush	Structural members
1045	0.40–0.50	....	....		Bars	.....	....	..	......	Forgings; cylinder sleeves
1050	0.45–0.55	....	....		Wire	140,000[3]–165,000	....	..	Bend	Tie rods, rolled or swaged
1085	0.80–0.90	....	....		Strip	.....	....	..	Bend	Flat springs
					Wire	190,000[4] 280,000			Torsion and bend	Tension members
1095	0.90–1.05				Wire	212,000[4] 350,000			Torsion and bend	Springs
2320	0.15–0.25	3.25–3.75	....		Bar	.....	....	..	......	Carburizing
2330	0.25–0.35	3.25–3.75			Bar	.....	....	..	......	Small forgings; gears; bolts
					Tube	.....	....	..	......	Axles
3140	0.35–0.45	1.00–1.50	0.45–0.75		Bar	.....	....	..	......	Forgings; conn. rods; bolts
X3140	0.35–0.45	1.25–1.75	0.79–0.90							Large forgings; crankshafts
3240	0.35–0.45	1.50–2.00	0.90–1.25		Bar					Large forgings
3250	0.45–0.55	1.50–2.00	0.90–1.25		Bar					Gears
6115	0.10–0.20	....	0.80–1.10	0.15–0.18[5]	Bar	.....	....	..	....	Carburizing; tappets
6130	0.25–0.35	....	0.80–1.10	0.15–0.18	Bar	.....	....	..	....	Screw machine parts
					Sheet	.....	....	..	Bend	Fittings
6135	0.30–0.40	....	0.80–1.10	0.15–0.18[5]	Bar	.....	....	..	......	Forgings; propeller hubs
6195	0.90–1.05	....	0.80–1.10	0.15–0.18	Bar	.....	....	..	......	Instrument parts
					Strip	.....	....	..	......	Springs
4130	0.25–0.35	....	0.50–0.80	0.15–0.25[6]	Bar	.....	....	..	......	Forgings; screw machine parts
X4130	0.25–0.35	....	0.80–1.10	0.15–0.25	Bar	.....	....	..	......	Forgings; screw machine parts
					Sheet	90,000	60,000	[7]	Bend	Fittings
					Tube	95,000	60,000	12	Crush	Structural parts; axles; piston pins[10]
2512	0.17 (Max.)	4.50–5.25	....		Bar	.....	....	..	......	Carburizing; Gears
3312	0.17 (Max.)	3.25–3.75	1.25–1.75		Bar	.....	....	..	......	Carburizing; Gears
				Silicon						
Corrosion resistant and valve steels	0.10–0.25	7.0–10.0	17.0–20.0	0.10.0.70	Bar	100,000	50,000	35	Bend	Non-magnetic parts
					Sheet	.....	....	..	Bend	Exhaust stacks; fittings
					Wire	125,000	....	..	Bend	Tie rods
	0.06–0.15	1.50 (Max.)	17.0 (Min.)	0.10–0.70	Wire	125,000	....	..	Bend	Tie rods
	0.30–0.40	0.50 (Max.)	13–14.5	0.10–0.50	Bar	.....	....	..	....	Special corrosion resistant parts
					Sheet	.....	....	..	......	Heat treated to 180,000 to 200,000 lbs./sq. in.
	0.35–0.50	....	7.0–9.0	2.75–3.75[8]	Bar	.....	....	..	....	Valve forgings
	1.00–1.50	....	11.0–14.0	0.20–0.30[9]		.....	....	..	....	Valve forgings

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[1] Sheet and tubing are 1025, bars may be 1020 provided physical requirements are met after normalizing.

[2] Minimum tensile strength 70,000/in.^{2}

[3] Wire less than 1/2″ in diam.

[4] Varies with size.

[5] Vanadium.

[6] Molybdenum.

[7] Elongation 2″—thicker than 3/16″—20%; 1/8 to 3/16—15%; 1/16 to 1/18—12%; less than 1/16—10%.

[8] Tungsten 2.00.

[9] Cobalt, 2.50-3.50 Mo, 0.50–0.90.

[10] Carbon, 0.50.

Non-Ferrous—Copper Base

Designation	Chemical Analysis Copper	Zinc	Tin	Lead		Form	Physical Properties Tensile Strength	Yield Point	Elong. 2″	Other Tests	Uses
Copper	99.88					Bar	30,000	....	25	....	Electrical conductors
						Sheet	37,000	....	20	Bend	Electrical conductors, radiator
						Tubes	30,000	....	25	Crush Hydrostatic	Water, oil and fuel lines
						Wire	Soft	....	..	Bend	Wrapping and locking
Brass	60	Rem	0.5–1.5	0.3 (Max.)		Bar	67,000	45,000	22	Bend	Turn buckles, non-corrosive bolts
	65	Rem	.....	0.3 (Max.)		Sheet	45,000	....	32	Bend	Gasoline tanks
	65–68	Rem	0.5–1.5	0.8 (Max.)		Tubes	.....	....	..	Flattening Hydrostatic Strain	Water, oil and fuel lines
	80	20	.....	....		Wire	.....	....	..	....	Brazing
					Phosphorus						
Bronze	Rem	0.30 (Max.)	4–6	0.1 (Max.)	0.01–0.25	Bar	60,000	40,000	10	Bend	Bushings
						Strip	100,000	50,000	0.1	Bend	Springs; clips
	55–60	38–42	1.5	0.2	Mn 3.5	Castings	65,000	....	20	....	Landing gear fittings
	85	5	5	5	Fe 2.0	Castings	27,000	....	15	....	Water, oil and fuel line fittings
	87	..	..	..	Fe 3, Al 1.10	Castings	65,000	....	15	Hardness	Bearings; bolts
	84	2.0 (Max.)	8	8		Castings	.....	....	..	....	Bearings and bushings
	80	..	..	..	Fe 0.5, Ni 0.5 Al 0.10	Castings	65,000	....	15	....	Bearings
	70	..	0–5	30		Castings	.....	....	..	....	Steel backed bearings

Non-Ferrous—Nickel Base

	Copper	Nickel	Iron	Mn	Form					Uses
Monel	23	60	3.5 (Max.)	3.5 (Max.)	Bar	80,000	35,000	35	Bend	Fittings
					Sheet	.....	....	..	Bend	Special tanks

Non-Ferrous—Aluminum Base

		Chemical Analysis						Physical Properties				
Designation	Aluminum	Copper	Iron	Silicon	Magnesium		Form	Tensile Strength	Yield Point	Elong. 2"	Other Tests	Uses
Aluminum	99 (Min.)						Bar	....	....	...	Bend	Welded parts; low stress
	99 (Min.)						Sheet	12,000	....	15–30^x	Bend	Cowling; tanks
								16,000	....	3–7^x	Bend	
								23,000	....	1–4^x		
	99 (Min.)						Tube	16,000	....	4	.....	Water, oil and fuel lines, fairing
	99 (Min.)						Wire	....	....	...	....	Welding
						Mn						
Aluminum	Rem	3.5–4.5	....	....	0.20–0.75	0.4–1.0	Bar	55,000	30,000	12–16^x	Bend	Fittings; forgings
	Rem	3.5–4.5	....	....	0.20–0.75	0.4–1.0	Sheet	55,000	30,000	9–15^x	Bend	Outside covering all parts, Structural-members
Alclad							Sheet	50,000	27,000	13–16x	Bend	Corrosion resistant parts
	Rem	3.5–4.5			0.20–0.75	0.4–1.0	Tube	50,000	40,000	12–16x	Crush	Structural parts
	Rem	4.5	....	1.0	....	.....	Forgings	55,000	....	16	Etch Brinell	Propellers, fittings, engine parts
	95			5			Wire	....	....	...	....	Welding
	95			5			Castings					Fuel tank fittings
	Rem	4–5	0.75 (Max.)	0.5 (Max.)	1.5	Ni 2.0	Castings	32,000	....	...	Brinell	Piston and cylinder heads
	Rem	10	1–1.5	....	0.35	.....	Castings	....	....	...	Brinell	Piston and cylinder heads
	Rem	4.5	1.0 (Max.)	1.0 (Max.)	....	.....	Castings	30,000	....	3	Brinell	Fittings, engine crankcases, water, oil

Non-Ferrous—Magnesium Base

Magnesium alloy	4	.....	....	....	......	Mn 0.35	Bars	40,000	....	8	....	Forgings
	6–7	.....	....	....	......	Mn 0.35	Castings	29,000	....	6	....	Engines, crankcases, cover plates

^{x} Varies with size.

The examination of aircraft material visually or under low magnification with or without etching is practiced to a considerable extent to determine quality. It is difficult to set a standard on the allowable surface defects or nonhomogeneity of structure but judgment tempered by a knowledge gained by the study of a number of failures will give a metallurgist a sound basis for accepting material. It is impossible to obtain commercial forgings absolutely free from hairlines. These defects are present in the steel billet, and it is the problem of the steel manufacturer to eliminate them. Hairlines which are perpendicular to the axis of the crankshaft are generally cause for rejection whereas those parallel to the axis are generally passed provided they do not occur in colonies. The failure of shafts containing an excessive number of hairlines would also indicate that the safest practice is to permit only a relatively small number, well scattered.

Tubing is used without removing the surface and contains relatively deep die marks, laps and scale pits. For ordinary statically loaded tension or compression members, these defects will not weaken the member but an examination of the curve (Fig. 3b) shows the effect of internal die marks on a 3/8 "O.D. × 0.032" tube under alternating stress in a rotating beam type fatigue machine. The effect is accentuated in heat treated tubes drawn below 700° F.

The uniformity of the wire used in the manufacture of aircraft bolts is tested on specimens taken from each end and the middle of the coil. The specimens are simply blanks taken after the cold up-setting operation to form the head. These blanks are milled and then etched in an aqueous solution containing 50% hydrochloric acid for about ten minutes and examined for any cracks or irregularity in the flow lines. Since this method of inspection was adopted, no failures have been experienced with this type of bolt.

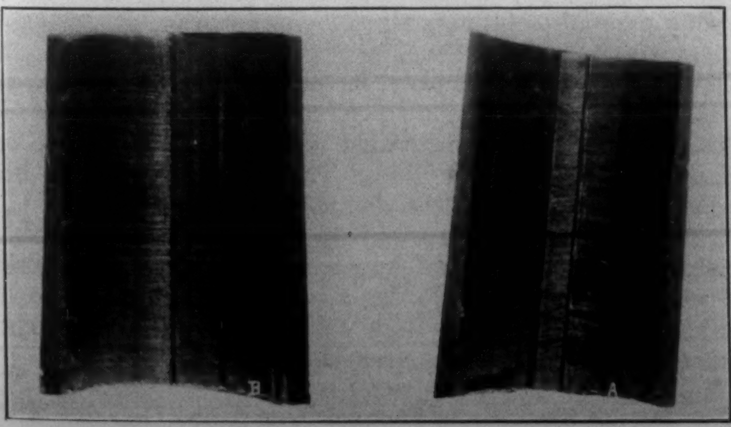

Fig. 3a—Character of Grooves in Tubing. Depth 0.002 to 0.004 in.

Aluminum alloy forgings and castings are etched in a sodium hydroxide solution followed by a dip in dilute nitric acid. Propeller forgings may be etched several times in the course of manufacture. It is also standard practice to etch after every 100 hours service.

Heat treatment has played an important part in the effort to reduce weight. The results obtained by heat treatment of long, slender parts, such as, wing beams and landing gear assemblies are very satisfactory. Welded chromium molybdenum steel, which has been used almost exclusively, can be quenched and drawn to develop tensile properties of 200,000 lbs./in.^{2} and 5% elongation. These properties are determined on a test specimen cut from the wall of the tube. It has been repeatedly demonstrated that the shock resistance of the material in this condition is adequate for the severe service. Wing beams and structural parts subject to vi-

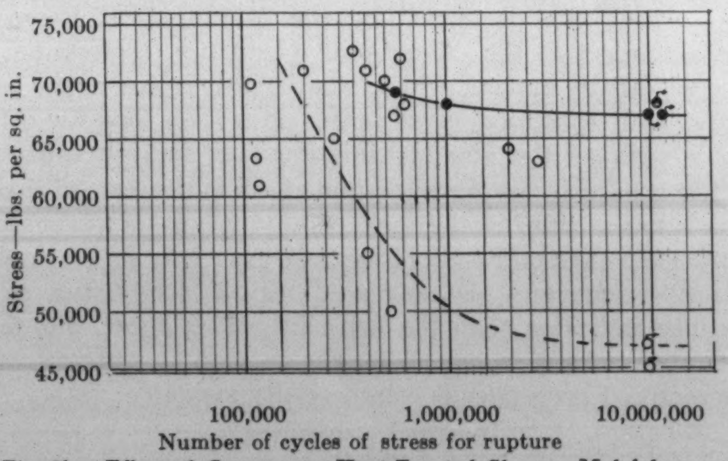

Fig. 3b.—Effect of Grooves on Heat Treated Chrome-Molybdenum Tubing

Dimensions of tube: 1/2" O. D. x .065" wall; heat treatment: Q oil 1625° F. D 650° F.; tensile properties: yield point 186,000 lbs./in.^{2}, tensile strength 208,300 lbs./in.^{2}, elongation 2" 6.5%

Solid line for tubes with grooves reamed out. Dotted line for tube as received. Wide scatter of points makes curve very approximate.

bration should be drawn at a temperature not less than 800° F. on account of the effect of unavoidable surface imperfections.

Electric furnaces with zone control give the best results. The furnaces are often built over the quenching tanks which permits very rapid quenching, decreases the scaling and reduces the temperature drop to a minimum.

Practically all non-ferrous parts of aluminum or magnesium alloys are heat treated. The heat treatment consists of a solution treatment followed by an aging treatment. The former is carried out at approximately 950° F. in the case of aluminum base and 800° F. for the magnesium base alloys. In the case of the wrought metal the time varies with the thickness and may be as low as ten minutes for very thin material up to 4-6 hrs. for forgings from 4-6″ in diam. The solubility is more sluggish in the sand cast material and requires from 16-24 hrs. A cold water quench is preferable. The aging may be done in air at atmospheric temperatures for thin members formed from sheet or in hot water, steam and electric furnaces at temperatures up to 300° F. for thicker sheets, forgings and castings. The ductility of the cast alloys of aluminum will decrease and the strength increase with an increase in the aging time.

The heat treated sand cast aluminum alloys are used extensively for fittings on the airplane and for engine parts. Physical properties generally specified are those in Table II and represent the low limits for commercial castings. It is possible by careful control to obtain tensile properties of 40,000 lbs./in.^{2}, and 6% per elongation. The properties for the magnesium alloys also represent heat treated material. Heat treated aluminum alloy forgings have replaced wood for propeller blades where maximum efficiency is desired. Forgings are also used for engine parts, such as, crankcases, gear covers and bearing blocks.

The preservation of the material in an airplane structure is just as important as the assurance that it had the required strength when it left the factory. None of the ordinary structural steels or hard aluminum or magnesium alloys will resist the action of salt water or an atmosphere charged with salt spray without serious deterioration. Protective coatings are necessary and these coatings should be developed by the metallurgist so that they will be an integral part of the metal. Coatings which are electropositive to the base metal are the best.

The best protection for structural steel, which is generally applicable to small parts is electroplating. Cadmium and zinc are used but the former is preferred, as it requires a thinner coat than the latter for equivalent protection. The passive surfaces obtained by etching and then polishing high chrome-nickel steels with chromium oxide give excellent protection.

The pure aluminum coating for the hard aluminum alloys which has been developed by the Metallurgical Research Department of the Aluminum Company represents an electropositive coating which is inherently a part of the base metal and, therefore, gives better protection than the other types such as the anodic oxidation and sprayed coatings.

The negligible use of magnesium alloys in the form of sheets and tubes is due to the lack of any means of preventing corrosion. The corrosion of castings especially in the engine is not serious and the increased use of magnesium alloy castings indicates that the aeronautical engineer will take advantage of any saving in weight as soon as material with the required properties is commercially available.

On February 28, the Driver-Harris Company gave a foundry demonstration of their new P. M. G. Metal, a high tensile strengh copper alloy, for the benefit of representatives of leading metal users and producers, government officials and the technical press at their plant in Harrison, New Jersey. Mr. F. L. Driver, Jr., President, presided at the meeting.

An Electrolytic Coating Process For Aluminum

The Metals Protection Corporation of Indianapolis, Ind., have announced their Alumilite coating process for electroplaters.

The process is an electrolytic method of applying an entirely new protective and decorative coating, Alumilite, to aluminum and its alloys.

It is understood that the application of this finish is made in a somewhat similar manner to the well-known anodic treatment but using an electrolyte containing sulphuric acid instead of the chromic acid of the older process.

The coating has shown a certain degree of resistance to certain chemicals, atmosphere, salt water corrosion and especial resistance to wear or abrasion. It is said that it will not chip, crack or peel off so the treated sheets may be stamped and formed into a wide variety of shapes.

Over sixty colors that have proved fast to light under the 300 hour fadeometer test are available with other colors under development. The finish is hard and does not tarnish, therefore it will not injure or discolor substances coming into contact.

The company claims that the cost is 30-75% less than nickel plating and that it is ready to install and start in operation plants for the process. Where a manufacturer does not require a private plant they are prepared to do job work.

Alloys of Iron Research

We learn from Dr. George B. Waterhouse that steady progress is being made in connection with this important project. Having originally set out to collect $150,000 the Committee is in the fortunate position of being able to report contributions amounting to upwards of $230,000.

Mr. F. T. Sisco has been engaged to direct the work of making a complete survey of the world's literature on alloy steels and alloy cast iron. He has established an office in the Engineering Building at 29 West 39th Street, New York. Certain definite portions of this work will be carried on under the direction of Dr. H. W. Gillett, at the Battelle Memorial Institute, Columbus Ohio.

Later provision will be made for original research to fill in some of the gaps in metallurgical knowledge indicated by the bibliographical research.

Research in Protective Coating Industry

The Paint and Varnish Division of the American Chemical Society is making a survey on research in the protective coating industry. It is hoped that this survey will show (1) the magnitude of research efforts in this country, (2) the extent to which there is duplication of effort and (3) which parts of the field are being intensively cultivated and which are being neglected. The survey should also direct attention to various new fields and suggest topics and individual problems which look promising.

The survey is being made by a joint committee under the auspices of:

The Paint and Varnish Division of the American Chemical Society.
The American Society for Testing Materials.
The Federation of Paint and Varnish Protection Clubs.
Scientific Section of the Educational Bureau of the American Paint and Varnish Manufacturers' Association.

The information sought is being secured by means of a questionnaire which will be circularized among all who might be carrying on research or development work of interest to the protective coating industry. The answers to the questions will be carefully studied and it is hoped that the results will justify the publication of a pamphlet outlining all of the problems.

Oxweld Acetylene Company, 30 E. 42nd St., New York, has placed on the market a welding rod for making extremely strong welds in steel, designated Oxweld No. 22 S. D. (Strength and Ductility) Steel Welding Rod. This welding rod has been especially made to meet the demand for 100% joints in steel pipe having a carbon content of 0.30—0.40%, which has recently come into use. In general appearance, weldability, chemical and physical properties No. 22 S. D. Rod is similar to the well-known Oxweld No. 1 High Test Rod, but it will produce welds of even higher tensile strength.

The Detroit Gray Iron Foundry Company, Detroit, Mich., announces the appointment of "Ted" Hill as Sales Manager. "Ted" is due to start making calls soon.

Effects of Silicon on the Properties of Brass[*]

By H. W. Gould[†] and K. W. Ray[‡]

I. Constitution

> *It is surprising, in spite of all the work that has been done on various alloy systems, how many systems remain to be explored. One would think that the effect of all the common, and especially the cheap elements, in so well-known an alloy as brass, would have been worked out long ago.*
>
> *This paper supplies basic information of a sort much needed to give a complete picture of the possibilities and limitations in the metallurgy of common metals. This is the sort of thing for which we look to the university laboratories and which should be forthcoming in greater numbers.*

Introduction

Comparatively little work seems to have been done on a study of the effects of silicon on the structure and properties of brass. However, temperature-composition diagrams have been worked out for the binary systems copper–zinc and copper–silicon.[1] Also, many properties of ternary and quaternary alloys are known, these alloys containing copper or copper and zinc.

Zinc forms homogeneous alpha solutions with copper in amounts up to about 30%. For compositions ranging between 30 and 45%, mixed alpha and beta or pure beta solutions are formed which may or may not be homogeneous according to the heat treatment employed. In a similar fashion, silicon forms a solid alpha solution with copper in amounts up to about 5%, while in amounts between 5 and $7^{1}/_{2}\%$ it forms a mixed alpha and beta mixture which is not homogeneous and whose constituency varies according to the heat treatment.

The ternary copper–zinc–silicon systems, for amounts of silicon up to about 5%, should be expected to form similar solid solutions, despite the fact that nothing is known about the solubility of silicon in zinc. Such an alloy, like the copper-silicon and the copper-zinc alloys, should be homogeneous for the alpha solid solution range after proper annealing.

A pure alpha brass, aside from crystal growth, is unaffected by heat treatment. The same applies to a beta brass, provided that the composition is such that the beta form is the stable form at all temperatures from the melting point down. If, however, a brass is of such composition that the constituents are not stable at all temperatures between the melting point and room temperature, then such a brass would manifestly be modified by heat treatment. A consultation of the temperature-composition diagrams for the copper–zinc and copper–silicon systems shows that many of these alloys should be modified by heat treatment.

It seems reasonable to suppose, therefore, that a ternary copper–zinc–silicon system, over certain constitution ranges, should show alloys susceptible to heat treatment. But since no work has been done on any part of the ternary temperature-composition diagram, the only prediction as to the constitution of silicon brasses must necessarily be based on the copper–zinc or the copper–silicon system.

W. Wunder[2] has recently determined the relative "zinc equivalents" for several elements in the alpha brass region, stating a value of ten for silicon. That is, a small amount of silicon, when added to an alpha brass, will produce the same effect (measured in terms of structural change and consequent physical properties) that would be produced by the addition of ten times that amount of zinc. By making use of this "zinc equivalent" for silicon, predictions may be made as to the constitution of a given silicon brass within the alpha range.

A study of the constitution of silicon brasses was desirable in order to show the value and range of usefulness of silicon, also to correlate the physical properties and corrosion resistance of the same alloys. The purpose of this investigation was, therefore, to make a study of the effects of silicon on the metallic constituents of brass. Since time would not permit a study to be made of the entire ternary copper–zinc–silicon system, nor even of all of the common brasses, a study of the effects of various amounts of silicon on the 85–15 and 60–40 brasses was undertaken. These effects were studied by means of the cooling curves of the alloys, by the microscopic appearance of annealed samples, and by the effects of heat treatment on the physical properties of the alloys.

Experimental Procedure

Electrolytic copper, in the form of shot, chemically pure zinc, in the form of sticks and crystalline silicon, in the form of lumps, were used in the preparation of the alloys. The two series of brasses that were investigated contained varying amounts of silicon up to 10%. Each sample was melted in a fire-clay crucible in a small, gas-fired crucible furnace. Three hundred grams of fresh metal were used for each melt.

Cooling curves were taken for alloys from both the 85–15 and the 60–40 series of brasses. Samples containing no silicon were also included. A chromel-alumel thermocouple was used, together with a Brown portable potentiometer which read directly in millivolts. It was previously calibrated by using the boiling points of water and sulphur, and the melting points of pure tin, antimony and copper as fixed points. The hot junction of the thermocouple was inserted through a hole in the cover of the furnace, and the metal was allowed to cool in the furnace. Readings were taken at half-minute intervals.

At a later date, the curves were rechecked. This time, a specially constructed electric tube furnace was used to remelt the alloys. Fifty-gram samples were melted in a fused quartz tube in an inert hydrocarbon atmosphere. The temperature during the cooling process was automatically recorded at 15-second intervals by a Brown recording pyrometer of 265 Ohms resistance. The cooling curves obtained by the two methods checked to within 2° C.

Samples were selected from different parts of the two series of brasses at sufficiently close intervals to show all the characteristic structures over the composition ranges studied, including pure brass. These samples were first examined (as cast) after they had been polished and etched. The etching agent used in most cases was a mixture of ammonium hydroxide and hydrogen peroxide. Each was then annealed to establish a condition of equilibrium. In annealing the samples, each was gradually raised to a temperature of 725–825° C., or to slightly below the melting point, maintained at this temperature for one to twelve hours, then allowed to cool slowly for several hours in the furnace.

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[*] Part I of an article to be published in two parts. Part II will appear in the May issue.

[†] From a dissertation presented by Mr. Gould to the Graduate College of the State University of Iowa, August 14, 1929, in partial fulfillment for the Ph.D. degree.

[‡] Metallurgy Division of the Department of Chemistry, University of Iowa, Iowa City, Iowa.

[1] *International Critical Tables*, **2**, 434–435 (1927).

[2] W. Wunder, *Zeitschrift Verein deutscher Ingenieure*, **73**, 165–168 (1929).

The samples were analyzed in order to determine the actual composition of the alloys formed. This was necessary, since the relative percentages actually found by analysis did not always check to within a reasonable degree of accuracy with the amounts originally melted together. The general method of analysis of the samples was to determine the silicon content by gravimetric methods, to determine the copper iodometrically, and to get the zinc by difference.

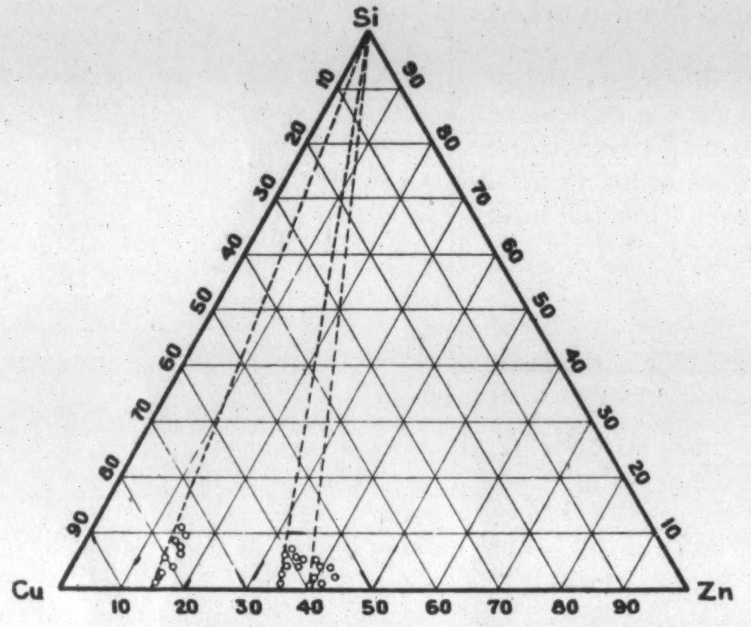

Fig. 1—Composition of Alloys Which Were Investigated

Data and Discussion

The microscopic examination of the alloys as cast revealed nothing except the dendritic structure peculiar to solid solutions which have been rapidly cooled. Therefore, the samples were annealed to bring out any distinct solid phases that might form. The evidence yielded by the cooling curves and by the microscopic examination agreed very well. Tables I and II are a summary of the conclusions reached.

Summary of Cooling Curve Data and Micrographs
Table I. 85-15 Brass Series

Percentage Composition			Beginning and End of Solidification		Other Points of Inflection		Solid Phases Present	Remarks
Si	Cu	Zn	Begin.	End				
0.0	85.6	14.4	1040	1010	None		Alpha Homogeneous	Malleable Soft
2.0	83.3	14.7	1005	960	None		Alpha Homogeneous	Malleable Tough
2.8	82.5	14.7	965	930	None		Alpha Homogeneous	Malleable Tough
3.3	82.1	14.6	950	870	700		Alpha-beta Alpha cont.	Malleable Tough
3.9	81.0	15.1	870	810	670		Alpha-beta	Elastic
5.1	80.2	14.7	845	810	755	655	Alpha-beta Beta cont.	Hard
5.2	80.6	14.2	850	810	755	655	Alpha-beta Beta cont.	Hard
6.0	79.8	14.2	825	780	650		Beta-gamma	Slightly brittle
8.5	77.9	13.6	780	745	650		Beta-gamma Gamma cont.	Brittle
8.6	77.7	13.7	770	745	None		Gamma	Very brittle
10.8	75.9	13.3	750	675	515		Gamma-epsilon	Very brittle

Further series were annealed at different temperatures, and hardness tests were made to determine as nearly as possible what alloys were most subject to heat treatment, also to serve as an additional aid in the interpretation of the constitution of these alloys. Fig. 2 shows the results for 85–15 brasses containing 3.9 and 5.1% silicon, also for 60–40 brass containing 0.8% silicon. A 58–42 brass series with no silicon was run with the others for purposes of comparison. Each series consisted of seven samples, one reserved as cast, the other six first heated to a temperature of 825° C. and quenched in ice-brine mixture. One of the six was tested as quenched; then each was annealed at a different temperature for approximately one hour. The temperatures were 750, 650, 550, 450, 350 and 250° C.

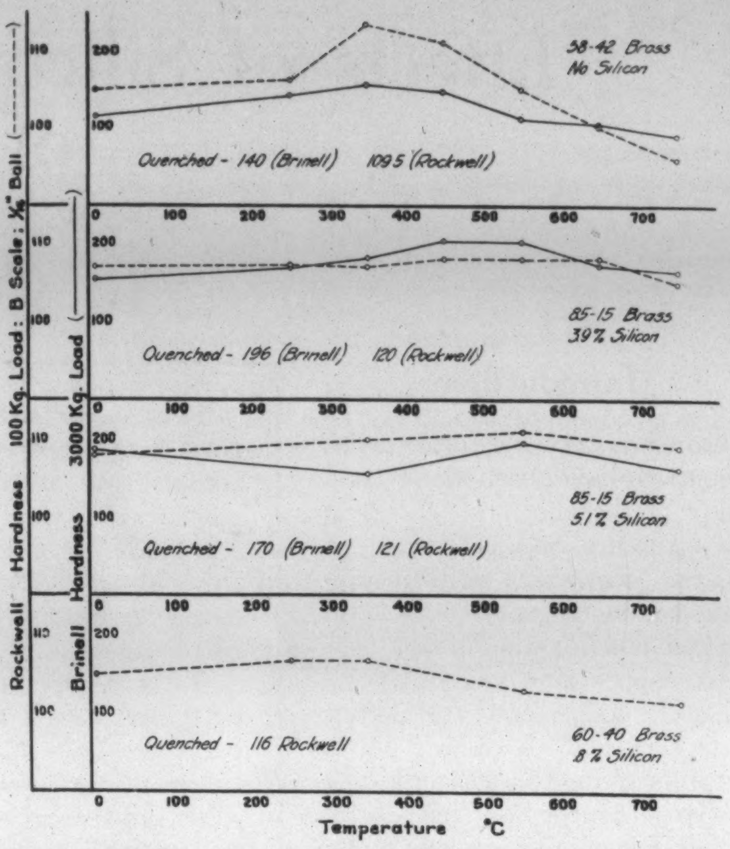

Fig. 2—Hardness Tests. Showing Effects of Annealing at Different Temperatures

Table II. 60-40 Brass Series

0.0	59.7	40.3	925	900	None		Almost Homogeneous	Malleable
0.8	58.8	40.4	883	875	725	650	Alpha-beta Alpha cont.	Hard
1.1	58.3	40.6	860	830	700	530	Alpha-beta Beta cont.	Hard
1.8	58.8	39.4	855	825	...	...	Alpha-beta Beta cont.	Hard
2.7	58.3	39.0	850	825	615		Beta-gamma	Slightly brittle
3.8	57.7	38.5	800	740	...	...	Beta-gamma Gamma cont.	Brittle
4.2	57.5	38.3	780	740	520		Gamma	Brittle
7.2	55.5	37.3	707	685	460		Gamma-epsilon Gamma cont.	Very brittle
7.3	55.6	37.1	705	685	...	...	Gamma-epsilon Gamma cont.	Very brittle

Hardness tests on the above treated samples yielded evidence of structural change as the result of the heat treatment. These changes in hardness were taken as an index of structural change. They were, therefore, a valuable check on points of inflection on cooling curves of alloys of the same composition, and were also useful in the interpretation of the microscopic appearance.

The results shown indicate a slight change in hardness for each of the three series tested. The maximum point occurs at about 500° C. for the 85–15 brasses and at about 300° C. for the 60–40 brass, indicating that a structural change must have occurred.

Although the changes in hardness were not marked, they were duplicated in successive independent series. They go to support the conclusions drawn from the cooling curves and the microscopic examination.

Conclusions for the 85–15 Brass Series

Silicon forms solid alpha solutions with 85–15 brass at 2.8%, as shown by the cooling curve for the the 2.8% sample.

A beta phase[3] appears at some composition between 2.8% and about 3.3% silicon. The cooling curve of 3.9% silicon shows a slight break beyond the point of complete solidification, indicating that the boundary line marking the temperatures and compositions at which the beta phase begins to appear is crossed at about 755°; also that the shift in structure has proceeded to at least the point corresponding to 40% zinc for the copper-zinc composition diagram. The alpha phase is continuous for 3.3% silicon, and discontinuous for 5.1% silicon. There is a point of inflection at 755°, also one at 655° for the 5.1% silicon alloy, indicating that the beta-alpha+beta boundary line is first crossed at 755°, and that then possibly a polymorphic change in the beta constituent occurs at 655°. These points of inflection are further supported by the varying hardness of samples annealed over this range of temperature. An alloy containing 5.2% silicon shows two phases, alpha and beta, with the alpha phase discontinuous and occupying about $^{1}/_{10}$ of the total alloy.

An alloy containing 6.0% silicon shows a point of inflection at 650° C. Also it is brittle, indicating that a new solid phase has appeared. This alloy probably consists of mixed beta and gamma crystals. The next alloy, containing about 8.5% silicon, still shows the two phases, beta and gamma, with the beta crystals almost absent, being present to the extent of about $^{1}/_{10}$. The cooling curve of another alloy containing 8.6% silicon shows no point of inflection below the solidus line. It is supposedly a pure gamma brass. The alloy containing 10.8% silicon again shows a point of inflection at 815°. Its constituency is taken to be gamma and epsilon. (The new phase is called epsilon rather than delta because the assumption is made that a delta phase, as in the pure copper-zinc series, is unstable at low temperatures, and breaks up into gamma and epsilon.)

Conclusions for the 60–40 Brass Series

A 60–40 brass with no silicon appears practically homogeneous when quenched from 825°. 0.8% silicon produces two phases which are very apparent. The two are present in about equal amounts, the alpha phase being continuous. There is a point of inflection at 725°, also one at 650°, on the cooling curve of this alloy, indicating that the beta-alpha+beta boundary line is crossed, also that there is a polymorphic change in the beta phase. These points are further confirmed by the heat treatment data mentioned above for an alloy of this composition. The 1.1% silicon alloy shows points of inflection at 700 and 530°, indicating that the beta-alpha+beta line is again crossed, this time at 700°; also that there is again the same polymorphic change at 530°. A 1.8% silicon alloy still shows the alpha and beta phases, but with the beta continuous and occupying about $^{4}/_{5}$ of the alloy.

A 2.7% silicon alloy shows a slight point of inflection at 615°. The fact that this alloy is slightly brittle indicates that the gamma solid phase has appeared, and that the constituency is mixed beta and gamma. A 4.2% silicon alloy shows a very slight point of inflection at 520°, indicating possibly a polymorphic change. Another alloy containing 4.0% silicon shows a homogeneous structure. Probably, then, these alloys are both pure gamma brass. Still another alloy containing 7.2% silicon shows a point of inflection at 460°, while one containing 7.3% silicon shows two constituents, a yellow phase being discontinuous. These alloys are taken to be composed of gamma together with some epsilon solid phase.

Fig. 3 is an equilibrium diagram showing the compositions of ternary silicon brasses consisting of pure alpha, of mixed alpha and beta and of pure beta solid phases at 800° C. It is constructed from data of the copper-silicon and copper-zinc systems, together with the information obtained from the thermal analysis and the microscopic examination of the alloys as above described. Since the entire region was not studied in this work, the diagram is not expected to be correct in all details. It merely represents the opinion of the authors. Such a diagram is of considerable value as a guide to further work in this region. It is, therefore, included.

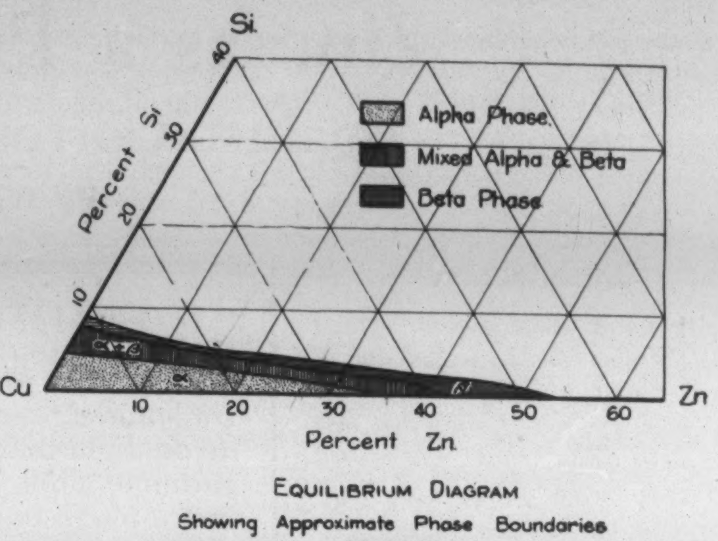

Fig. 3—Equilibrium Diagram Showing the Approximate Compositions of Ternary Silicon Brasses Consisting of Pure Alpha, of Mixed Alpha and Beta and of Pure Beta Solid Phases at 800° C.

Summary and Conclusions

1. The structure of brass containing silicon has been studied for two copper-zinc ratio series.
2. Silicon forms homogeneous alpha solutions with 85–15 brass if present to the extent of not more than 2.8%. It does not form homogeneous alpha solutions with 60–40 brass.
3. The range for mixed alpha and beta solid phases is about 2.8 to 5.2% silicon for 85–15 brass, and 0% to about 2% silicon for 60–40 brass.
4. Silicon forms a homogeneous gamma solid solution with 85–15 brass at 8.6%, and with 60–40 brass at about 4.2%. All other brasses in the two series show two solid phases.
5. Silicon lowers the freezing point of the 85–15 and 60–40 brasses when present in amounts up to 10 and 7%, respectively.
6. Many of the silicon brasses are subject to heat treatment.

Graduate Courses in Metallurgy

Graduate courses leading to the doctor's degree in metallurgy will be offered by the Department of Mining and Metallurgy at the Carnegie Institute of Technology, Pittsburgh, Pa., beginning in the fall of 1930. This is the natural outgrowth of the program of research in steel and coal projected by the institution, which originated in the belief that there is an acute need for a more comprehensive study of the science of metals and that theoretical knowledge has lagged far behind the demands of industry. Particular emphasis will be placed on the study of special steels, about which knowledge is lacking, and as the work progresses it is proposed that the students shall make detailed studies of mills where specialized products are manufactured.

Dr. H. E. Foote has been appointed to the incumbency of the Industrial Fellowship on Oxygen at the Mellon Institute of Industrial Research, Pittsburgh, Pa. This fellowship has been established by the Gas Industries Co., Inc., Pittsburgh, Pa., designer and builder of liquid-air oxygen apparatus. The investigation is to be concerned with the extension of the present uses of oxygen and in particular with the application of cheap oxygen in various industrial processes, including metallurgical operations and technically important organic oxidation reactions.

Dr. Foote has been a member of the Institute's investigational staff since 1927. He was previously engaged in research at the Philippine Bureau of Science, Manila, P. I.

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[3] The solid phases that appear with increasing percentages of silicon are named alpha, beta, gamma, etc., in the same manner in which the solid phases are designated in the Cu–Si or the Cu–Zn systems. No attempt is made to characterize the individual phases. There is no evidence of compound formation within the range of compositions covered by the study.

Zinc as a Protective Coating
Against Corrosion Fatigue of Steel

By Wilber E. Harvey*

> ***On page 115 of our September issue, we remarked that, among other coated metals, "hot galvanized, sherardized and zinc-plated steels should be studied" to throw light on the problem of the propagation of a notch through a brittle coating into a tough base.***
>
> ***This paper comes as a prompt answer to our prayer. This very definite indication of the danger that lies in brittle coatings leads us to hope for much more work along similar lines.***

Introduction

Additional experiments showed that the abnormality is not due to the thermal but to the chemical effect of water upon steel, and that this chemical action has unexpected influence on the "fatigue-resisting" properties of the steel.[1]

This paragraph appeared in a paper presented by McAdam[2] to the A. S. T. M. at its annual meeting in 1926 and affords what is believed to be the first reference to the combined effect of repeated stress accompanied by the corrosive action of ordinary carbonate water. At present, the discovery of the "corrosion-fatigue" phenomenon is universally recognized as one of the eminent metallurgical achievements of the twentieth century. Within four years of its initial study, corrosion-fatigue has been recognized as a vital problem to every engineer whose products are subject to repeated stress.

Résumé of Corrosion-Fatigue

Dr. D. J. McAdam, Jr., of the Naval Engineering Experiment Station was the pioneer in the study of repeated stresses as affected by corrosion. He reported that there is no plain carbon or alloy steel, other than the so-called stainless variety, which has a corrosion-fatigue value exceeding 25,000 lbs./in.^{2} By corrosion-fatigue value or limit is meant the highest stress which a metal will endure indefinitely when subjected to repeated stresses and exposed simultaneously to the corrosive influence of a stream of water. "Indefinitely" is often accepted as meaning 10,000,000 cycles of stress under alternating flexure tests, on ferrous materials. The corrosion-fatigue limit of a metal or alloy, of course, cannot be a constant but only becomes a definite value for one particular corrosive medium. For example, the corrosion-fatigue limit of a steel exposed to the corrosive action of salt water is generally lower than that when exposed to fresh water which has a high content of carbonate. The carbonate which is precipitated upon the surface of the steel after a certain time seems to form a coating on the steel which is protective to the underlying metal. The protection is probably due to the imperviousness of the carbonate coating to the water which is flowing over it.

The composition of the steel, its heat treatment and any previous cold-working done upon it seem to have no effect upon the corrosion-fatigue limit of the steel except as they affect the corrosion resistance of the alloy. There does not seem to be any relation between the corrosion-fatigue limit of a metal or alloy and any of its mechanical properties. The fatigue limit of the metal under water seems correlated only with the electrolytic solution pressure of that metal or alloy for that particular corroding medium. It does appear, however, that the electrolytic solution pressure of a metal under stress differs from the electrolytic solution pressure of the truly unstressed metal. The tendency of a stressed metal to dissolve is not measured by its solution pressure in the unstrained condition but by an electrolytic solution pressure increased probably in the proportion that the stress has been raised. The direct relationship between stress and solution pressure has not been determined as yet, but it is known that as the stress increases the solution pressure also increases. When corrosion cracks are formed as the result of original corrosion pits, and if these corrosion cracks increase the local stress and diminish the safe area of the sound metal to such a degree that the actual stress in the sound metal at the base of the corrosion cracks exceeds the endurance limit of the metal in air, then failure occurs, even though the nominal designed stress may not be exceeded. For stresses well below the corrosion-fatigue limit, the stress is never high enough to cause ultimate failure. At stresses below the corrosion-fatigue limit one or two things may occur to prevent the ultimate failure of the metal. Either a carbonate coating fills the corrosion cracks and prevents the water from entering to continue its eating action on the metal or else there is a strengthening effect at the base of the corrosion cracks in the steel due to a cold-working effect. This strengthening effect renders the steel less vulnerable to the effects of fatigue. It is very probable that there may be a combined effect of these two conditions.

The corrosion-fatigue limit range for all steels other than the so-called stainless irons and steels lies between 12,000 and 25,000 lbs./in.^{2} It was also pointed out by Dr. McAdam that in the lower range are found the pearlitic low carbon steels and the sorbitic higher carbon steels. At the upper limit of the range the sorbitic low carbon steels are found and also the pearlitic higher carbon steels. Alloying elements do not affect this range other than they may affect the corrosion resistance of the alloy itself. Even copper, which is added to steel in slight quantities to aid in the prevention of ordinary atmospheric corrosion, has practically no effect upon the corrosion-fatigue resistance of steel.

The high chromium content irons and steels have been reported to have corrosion-fatigue ranges of 30,000 – 40,000 lbs./in.^{2} This doubles the average value obtained with the ordinary steels but the cost of the corrosion resistant steels limits their use.

Either one of two things must be done before safe loading can be put into members which are subject to the combined action of repeated loading and corrosion.

(1) Corrosion must be eliminated in some way, or

(2) Protective coatings which will protect the vulnerable material must be found.

Efforts toward both ends have been begun and there have been works published upon each. Mr. F. N. Speller has succeeded in the inhibition of corrosion by the use of such inhibitors as potassium chromate and potassium dichromate, the chromate being the more successful. However, as yet this does not seem to promise an adequate solution to the general problem, since it is only applicable in closed systems.

Metallic protective coatings for base metals seem to offer the best protection against corrosion accompanied by fatigue.

Dr. McAdam[3] gives results upon heat-treated chromium vanadium steel which had been electro-plated with chromium. The chromium plated specimens were subjected to corrosion-fatigue tests in carbonate water but the coating formed practically no protection for the underlying steel. Unfortunately the chromium was plated directly upon the steel and not upon an intermediate coating of copper or nickel, which affords the best chromium plating conditions. In the same paper results were reported upon cadmium plated specimens. With a cadmium coating of 0.0002″ the corrosion-fatigue limit was raised from 18,000–35,000 lbs./in.^{2} With 0.0004″ the corrosion-fatigue limit was raised still higher to 42,000 lb./in.^{2} The endurance limit of the bare steel in air was 70,000 lbs./in.^{2}

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* Dept. of Metallurgical Engineering, Lehigh University, Bethlehem, Pa.

Fuller[4] tested a couple of hot galvanized specimens that had been corroded a week in tap water, at a single stress above the endurance limit of the uncoated steel, 90,000 lbs./in.^{2}, and found that the number of cycles endured was less than with similarly corroded uncoated specimens, due to cracks in the brittle iron-zinc alloy layer. Relatively little study has been given to zinc coatings, hence work was begun upon them at Lehigh University.

Requirements of Protective Coatings

The selection of a metal for a protective coating against corrosion-fatigue is not an easy task. There are several requisite properties of a coating that must be considered:

1. Adherence to the base metal.
2. Electropotential.
3. Porosity of the coating.
4. Physical properties of the protective metal.

These properties are not arranged in the order of their importance because that order would be changed under various conditions.

The necessity of good adherence between the base metal and the coating metal need not be emphasized. There must not exist any tendency for the coating metal to spall from the base metal. If the surface metal peels from the base metal after a few repetitions of stress and exposes the underlying metal to the corroding medium, a galvanic cell will be set up between the two metals. This would, of course, accelerate the corrosion of either the coating metal or the base metal. In some cases intermetallic compounds are formed between the two metals. An example of this is the series of iron-zinc compounds which are formed when iron or steel is hot-dipped in zinc. The alloying effect between the two metals forms a very strong union and assures a good adherence of the protective coating, at least when the coated material does not have to withstand deformation. These compounds are only formed when the two metals are joined at a somewhat elevated temperature, about 450–470° C. In electroplating it is quite probable that there is a free atomic bond extending outward from the surface of the base metal to which the plated ion of the deposited metal attaches itself. Regardless of the explanation of the union between the two metals it is accepted that there is some force exerted between the two surface layers of metals in electro-deposition which affords adherence.

When searching for a protective metal it is customary to consider the position in the electropotential series of the coating metal. If the coating were not porous and never became discontinuous, then it would always be advisable to use a protective coating of a material which had a lower electropotential, since the tendency of the metal lower in the electropotential series to corrode is less than that of the baser metal. An example of this is the tinplating of iron and steel. However, were the coating ever non-uniform or if it should peel from the underlying metal, then the underlying metal, electropositive to the protective layer, would corrode at an accelerated rate. It is quite obvious that under these circumstances it would be far better to use a metal which would be electropositive to the base metal and would be dissolved while saving the base metal. The position in the electropotential series, however, is not always a true criterion of the tendency of a metal to corrode since a metal may form a protective oxide film on its surface which is insoluble in the attacking medium. It is well known that aluminum will not dissolve in nitric acid since the oxide of aluminum is formed on the surface of the metal and Al_2O_3 is insoluble in nitric acid. Thus, aluminum would form a protective coating for zinc in nitric acid even though aluminum stands higher in the electropotential series than zinc.

The necessity for a non-porous coating depends quite a little upon whether the coating is electropositive or electronegative to the base metal. If the protective coating is electronegative to the base metal then it is necessary that the coating be very dense and non-porous. If, on the other hand, zinc is used as a coating on steel then the porosity is not such an important problem since the iron will always be protected at the expense of the zinc, regardless of whether the water penetrates through the zinc coating or whether it is absolutely impervious to the water. In every instance, of course, as impervious a coating as possible is desired. If the zinc coating is impervious then the tendency of the zinc to pass into solution is measured by its electropotential. If water penetrates through the coating then galvanic action between the zinc and the iron sets in and the zinc is dissolved, thus protecting the iron.

If the coated material is subject to external stress in addition to corrosive action then the physical properties of the metal must be studied. In a rotating beam specimen the most severe strains are exerted on the fibers which are most distant from the neutral axis of the beam and the fibers in this section show the most distortion under strain. The protective coating, since it is on the exterior of the specimen, will be exposed to the most severe distortion. Extreme care must be used in the selection of a coating in order that the coating can and will undergo the distortion to which it is subjected without cracking or buckling. Assume the base metal to have a higher elastic limit than the protective coating. With the application of a sufficiently high stress the elastic limit of the base metal is exceeded. The most severe permanent deformation will be in the outer fibers of the steel, and if the protective coating cannot take up the distortion then it will crack and break off, exposing the underlying metal. If the elastic limit of the exterior coating is higher than that of the steel the coating will be cracked away. However, if the elastic limit of the coating metal is lower than that of the base metal a different action occurs. As stress is applied, the elastic limit of the coating is first exceeded. It deforms without cracking if it possesses enough ductility.

Selection of Zinc Coating

Such considerations make it obvious that zinc coatings should form a fairly good protection against corrosion-fatigue. In addition, zinc coatings have the advantage that they are cheap, readily applied and are commercially used. The selection of the proper type of zinc coating was considered a worthy study and it was decided to run tests upon several kinds of zinc coatings in order to determine which might offer the most protection to the underlying steel against the combined action of repeated stress and corrosion. In order that the zinc coatings might represent the very best commercial practice the help of several companies was enlisted in the coating of the specimens.

Equipment and Material

The R. R. Moore rotating beam type fatigue machine was used in all the tests. A few minor changes were made to the machine but only such as were necessary for the application of water to the specimens. The speed of the machine was 1750 r. p. m. and all the tests were run at this speed, in order that the results obtained might be comparable to those obtained by other investigators since ordinarily a speed ranging from 1400–1800 r. p. m. is used in fatigue studies. The standard R. R. Moore type specimen was used for all the tests with the exception that the fillets were made slightly larger than usual in order to facilitate polishing the fillets. With the usual fillets it was found to be difficult to polish in the fillets and rather than have an imperfect polish it was decided to enlarge the fillet. The diameter of the reduced section of the specimen was 0.300 in.

A fairly hard steel was used in all the tests in order that the range between the endurance limit in air and the fatigue-limit in water might be wide and afford a better opportunity for studying the protective effects of the zinc coatings. By using a fairly hard steel the notch effects of the iron-zinc alloys would be more accentuated. Accordingly a steel of the following analysis was chosen and was kindly supplied by the Bethlehem Steel Company.

Carbon	0.47%
Manganese	0.64%
Phosphorus	0.01%
Sulphur	0.035%

The steel was supplied in seven-eights inch round rods and was given the following heat treatments in the Metallurgical Laboratories of Lehigh University.

Heated to 1650° F.—cooled in air.
Heated to 1575° F.—quenched in water.
Heated to 1125° F.—cooled in furnace.

The tempering temperature is above the temperature reached in hot-galvanizing or sherardizing. In each heat treatment the rods were held at the required temperature for one hour before cooling. A microscopic examination checked the sorbitizing treatment. With this heat treatment the steel possessed the following properties:

Tensile Strength	105,500 lb./in.^{2}
Proportional Limit	62,500 lb./in.^{2}
Elastic Limit	62,500 lb./in.^{2}
Yield Point	68,250 lb./in.^{2}
Elongation (2 in.)	21%
Reduction of Area	48%
Modulus of Elasticity	29,100,000 lb./in.^{2}

The machining of the specimens was done by the Bethlehem Steel Company and particular care was taken that too heavy cuts were not taken from the surface, to avoid possible hardening of the surface layers. The specimens were then polished through the following stages:

(1) A longitudinal polish using No. 180 Aloxite cloth.

(2) A longitudinal polish using No. 240 Aloxite cloth.

(3) A circumferential polish using a canvas wheel with flour of emery in kerosene as an abrasive.

(4) A longitudinal polish using No. 320 Aloxite cloth wetted with kerosene. The final polish was longitudinal in order to avoid any possible notch effect that a circumferential polish might afford.

The water used during the test was Bethlehem City tap water which is substantially a carbonate water and of which the following analysis is typical:

	P. p. m.
Total Residue	134,500
Fixed Residue	128,600
Loss on Ignition	5,900
Total Hardness, Soap Method, as $CaCO_3$	80
Permanent Hardness, Soap Method, as $CaCO_3$	67.1
Temporary Hardness, by difference, as $CaCO_3$	12.9
Oxygen Consumed	4.2
Alkalinity as $CaCO_3$	33.7
Non-carbonate Hardness as $CaCO_3$	31.7
Chlorine as Chlorides	10.7
Sulphates as Sulphur Trioxide	72.4
Total Acidity	15.9
Mineral Acidity	0.0
Free Carbonic Acid	3.8
Silicon Dioxide	7.4
Iron and Aluminum Oxides	3.2
Calcium Oxide	28.8
Magnesium Oxide	6.0

The hot-dipped specimens were galvanized by the New Jersey Zinc Company. They were subjected to the usual commercial process. The average weight of the zinc coating was two ounces per square foot which afforded a zinc coating of about 0.003 in. in thickness.

The General Electric Company did the sherardizing of the specimens and again the usual commercial process was used. The thickness of the sherardized coating was 0.002 in.

The electro-plating of the zinc was done in the Bell Telephone Laboratories. The weight of the zinc coating was as an average 136.6 mg./in.^{2} which gave a thickness of about 0.0011 in. At the writer's request the specimens were not pickled in the usual baths but were merely cleaned by degreasing with alcohol and ether. The effects of the acid upon the steel were in this way avoided. While this is not the usual procedure in commercial plating it was thought advisable since one would expect a better protection against corrosion-fatigue without the use of a pickling bath and it was the purpose of this experiment to secure the type of zinc coating most resistant to corrosion-fatigue. None of the specimens were polished after coating.

Procedure of Test

The results of uncoated specimens run in air and in water are shown in Fig. 1. Each point represents a specimen which was broken with the exception of those marked as removed. The specimens which were run in air were cleaned thoroughly with alcohol and were given a thin coating of oil. The fatigue limit of the bare polished steel specimens in air is shown to be about 60,500 lbs./in.^{2} The uncoated specimens which were run in water were also cleaned very carefully with alcohol to remove any grease that might be on the surface of the specimen and might restrict the water from reaching the surface of the steel. The stream of water was applied at right angles to the specimen and the water covered the specimen for a distance of about three-quarters of an inch in its region of maximum stress. There was no difficulty from the specimens breaking in any place other than the region of maximum stress. At all times the temperature of the water was about that of the temperature of the room and ranged between 65 and 76° F. The corrosion-fatigue limit of the uncoated steel in plain water was about 20,000 lb./in.^{2}

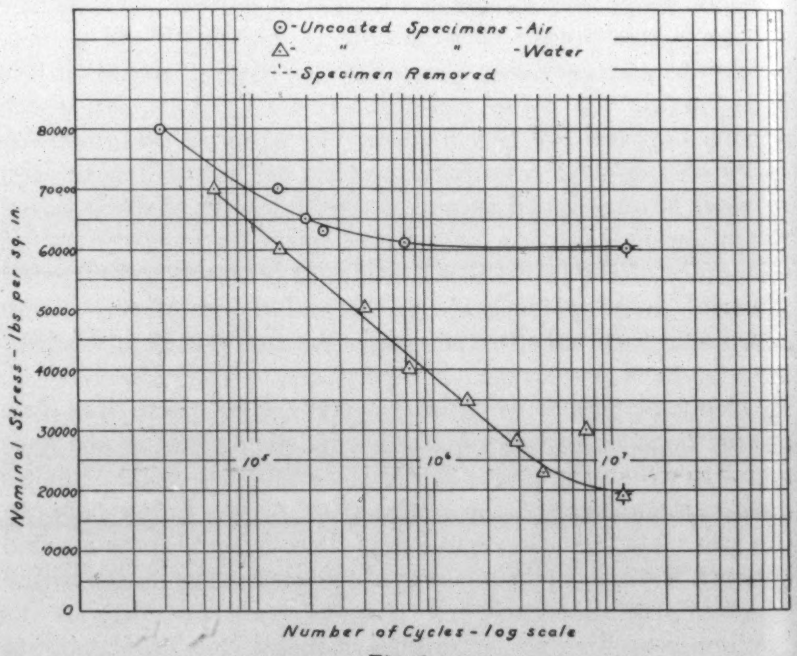

Fig. 1

The zinc coated specimens were run in water in exactly the same manner as the uncoated specimens. A little trouble was encountered in keeping the galvanized specimens free from vibration as the tapered ends of the specimen had been galvanized also. This zinc-coating on the tapered end was removed before insertion in the machine after it was found that it caused eccentricity in the specimen. Again no trouble was experienced with the specimens breaking outside of the region of maximum stress. The results of the individual specimens are shown in Fig. 2. The zigzag lines shown for the galvanized and sherardized specimens which ran ten or more million cycles show the life at the initial stress at which the specimen was run and also the stress to which the specimen was raised and the life of the specimen at the higher stress. Specimens which had endured ten or more million cycles of stress were removed from the machine unbroken. All of the testing was done upon one testing machine

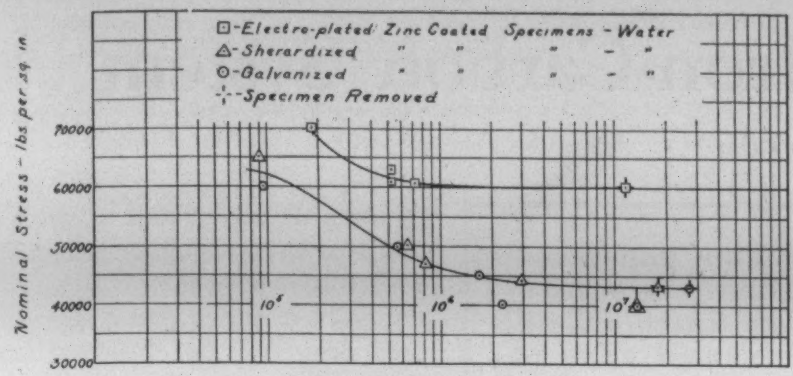

Fig. 2

and time had to be conserved. One of the galvanized specimens broke very short. This was due to a very severe vibration which was set up in the specimen and its value is of no use at all in the plotting of the curve. The result was not omitted, however, since the uniformity of test results should be shown. Its breaking short was not due to any condition other than excessive vibration. The fatigue limits of the unpolished zinc coated specimens under water were:

Galvanized zinc coating	43,500 lb./in.^{2}
Sherardized zinc coating	43,500 lb./in.^{2}
Electroplated zinc coating	60,500 lb./in.^{2}

Discussion of Results

Fig. 2 reveals that the sherardized and galvanized specimens seem to act exactly the same under the conditions of corrosion-fatigue. Since their values fall along one path, one curve is used to represent the value of both.

The temperature of the galvanizing and sherardizing processes are about the same. In each case there is known to exist a layer of intermetallic compounds which grade from high iron content on the interior to high zinc content near the pure zinc surface. A microscopic examination of the failed specimens was made in some cases and this examination substantiates the presence of the intermetallic compounds, as shown by F. N. Speller in "Corrosion."[5] It is true that sherardized coatings are usually more porous than galvanized coatings yet this does not affect the corrosion resisting qualities of the coating. The ordinary pickling baths that are used in the preparation of the steel for the zinc coating are also quite similar for both the sherardizing and the galvanizing operations. The conditions used in sherardizing and galvanizing operations closely approximate each other and it seems quite fair to assume that the coatings would have the same resistance to corrosion-fatigue. It was not expected, however, that the curves would so exactly coincide with each other.

It might not be expected that the electroplated zinc surface would form a better protection for the steel against corrosion-fatigue than the galvanized or sherardized coating. It is well known that the latter two coatings are usually two or three times the thickness of electroplated zinc surfaces and it would seem as if they would form a better protection against corrosion, since zinc compounds are also electropositive to the base metal. But while these zinc-iron compounds, which are present in the sherardized and galvanized coatings but absent[†] in the electroplated surfaces, may possibly add to resistance to stressless corrosion, they present a menace under corrosion-fatigue conditions in that they afford a notching effect. Intermetallic compounds are very hard and brittle and the iron zinc compounds are no exception to this law. Hence, when the outermost fibers of the steel begin to distort under stress this hard brittle compound is unable to yield to the change in shape of the steel and cracks are set up in the compound layer. These cracks which are started in the compound layer are quite readily propagated into the underlying metal and if the base metal is at all hard, the tendency of the crack in the compound is to pass directly through to the steel and cause quite rapid failure even though the water might not have touched the steel at all. This seems to afford a logical explanation for the electroplated surface offering the better protection against corrosion-fatigue since there did not appear to be any corrosion of any of the zinc coated specimens.

In the galvanizing and sherardizing processes, if the steels are subjected to a pickling bath there is always the possibility of the presence of some entrapped hydrogen in the outer layers of the steel unless the material is annealed to expel the gases. The presence of this gas in the steel tends to make the surface of the steel more brittle than if it possessed no entrapped gas. With the electroplated zinc coating used in this experiment no pickling process was used in cleaning the steel. In order to study the effects of entrapped hydrogen a set of electroplated specimens made by the commercial method is now under test. The results of these tests will be embodied in a future report.

Conclusions

From the results obtained it appears as if the zinc surface in each of the sherardized, galvanized and electroplated coatings prevents any of the water from reaching the surface of the underlying steel and that the effects of corrosion are entirely eliminated. This is most strikingly shown by the electroplated specimens where the corrosion-fatigue limit of the uncoated specimens in air is exactly the same as the fatigue limit of the electroplated specimens in water. All that the zinc has succeeded in doing was to make the steel water-proof. The same "water-proofing" occurred with the galvanized and sherardized coatings but in each of these cases the presence of the hard brittle intermetallic compounds caused a premature failure. This premature failure may have been accelerated by the presence of hydrogen gas in the steel after pickling. The results of a test which will show whether or not the absorbed hydrogen has any effect upon the corrosion-fatigue limit will be offered in a later report. With a suitable coating the fatigue limit of a metal in water like the endurance limit in air will range from 40–50% of the tensile strength of the metal.

Since the corrosive effect of water upon steel can be prevented by a suitable coating like electroplated zinc, the corrosion-fatigue limit of the steel need no longer be considered. As long as the coating remains continuous the fatigue limit of the coated steel in water would be equal to the fatigue limit of the uncoated steel in air and a steel could be stressed to the endurance limit even though exposed to corrosive conditions. Instead of a maximum stress of 25,000 lb./in.^{2} with the uncoated steel, 40–50% of the static tensile strength could be applied to a zinc coated steel without failure even though exposed to corrosive conditions.

From the results of the tests reported upon in this paper it appears as if an electroplated zinc coating, in whose preparation the usual pickling process has been eliminated affords very complete protection for steel against corrosion-fatigue.

Acknowledgments

Many thanks are due to the following members of the faculty of Lehigh University for their useful advice and encouragement in this work: Professors Bradley Stoughton, Allison Butts, Gilbert E. Doan, W. A. Slater and M. O. Fuller. The cooperation of the Bethlehem Steel Company, New Jersey Zinc Company, Bell Telephone Laboratories, General Electric Company and the United States Navy Department was sincerely appreciated. The assistance of Messrs. T. E. Brower and Roy E. Campbell in the execution of certain parts of experimental work was invaluable.

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[5] F. N. Speller, "Corrosion, Its Causes and Prevention," 1926, pages 313–316.

[†] Proven by microscopic examination of specimens.

The Solidus of the Iron-Carbon System

By O. W. Ellis[*]

This is one of the series of papers and correlated abstracts relating to parts of the Iron-Carbon diagram which are still in doubt. This is commented upon on the editorial page.

The publication of the third report on the Heterogeneity of Steel Ingots by a Committee of the British Iron and Steel Institute in the one hundred and ninth Journal of the Society may serve as a reminder to those interested in the alloys of iron and carbon of the somewhat remarkable differences of opinion which have existed, and still exist, in regard to the position of the solidus in the equilibrium diagram of this system.

The position of the solidus was quite unknown until the classical work of Carpenter and Keeling[1] showed it to extend in a straight line from 1505° C. at zero carbon to 1130° C. at 2.0% carbon. In their work Carpenter and Keeling used thermocouples which had been compared directly with one of the standard couples of the N. P. L. The latter had itself been calibrated up to 1000° C. against a nitrogen thermometer. At the time of Carpenter and Keeling's experiments no reliable data existed regarding the gas scale for temperature in excess of 1000° C. Hence, these temperatures were calculated on the assumption that the cubic equations representing the relationships ($E = a + bt + ct^2$) between the e. m. fs. and the temperatures of the thermocouples used held good up to 1500° C.

A critical study of the freezing point of iron by Carpenter[2] in 1904 served to confirm his opinion that the freezing point of iron on the thermo-electric scale was 1505° C. This he found, from a study of Burgess' work[3] on the corrections that should be added to thermo-electric determinations to give temperatures in terms of the optical scale, corresponded to a temperature of 1519° C. on the optical scale which, he opined, was the nearest approximation to the true value of the freezing point of iron in 1904.

Since 1910 the nitrogen scale has been extended, and on the basis of the work of Day and Sosman,[4] and of Waidner, Mueller and Foote[5] in the United States, and of others elsewhere, a series of points on the International Temperature Scale, which are used in the calibration of secondary temperature measuring instruments, has been agreed upon.[6] On this scale the melting point of palladium is 1555° C. Assuming the melting point of palladium to be 1555° C., Tritton and Hanson[7] have obtained the value 1535° C. for the melting point of iron.

In Andrew and Binnie's[8] experiments, a tungsten-molybdenum couple was used. This was calibrated against a standard platinum/platinum-rhodium couple for temperatures below 1200° C. The equation for the molybdenum-tungsten couple was of the form $\gamma = CX^2$, and by extrapolating to the melting point of Armco iron, Andrew and Binnie obtained the value of 1537° C. for this "constant."

In the light of the foregoing discussion it is of considerable interest to compare the values for the liquidus of the iron-carbon alloys examined by Carpenter and Keeling in 1904 with those obtained by Andrew and Binnie for a somewhat similar series in 1929. This is done in Fig. 1, in which the upper line shows the liquidus according to the latter, the lower line that according to the former investigators. The remarkable agreement between the two sets of observations is well worthy of note.

If it be assumed that a straight line best fits the observations within this range of temperature and carbon content—in other words, that Raoult's law holds up to about 1.5% C., the following rather interesting facts emerge:

(I) The equation for the best straight line (as determined by the method of least squares) for all of Carpenter and Keeling's observations, up to and including that for 1.31% carbon steel, is $T = 1507.7 - 63.9C$ (a), where T is the liquidus (° C.) and C the carbon content (%).

(II) That for all of Carpenter and Keeling's observations, up to and including that for 0.85% carbon steel, is $T = 1507.6 - 63.0C$ (b).

(III) That for all of Carpenter and Keeling's observations, up to and including that for 0.60% carbon steel, is $T = 1507.7 - 63.3C$ (c).

(IV) That for all of Andrew and Binnie's observations, up to and including that for 1.22% carbon steel (omitting one high-phosphorous alloy, and assuming the Armco iron to contain 0.01% C), is $T = 1537.1 - 63.1C$ (d). When the Armco iron is assumed to be carbon free, the equation is $T = 1536.9 - 62.9C$ (e).

(V) That for all of Andrew and Binnie's observations, up to and including that for 0.71% carbon steel (omitting one high-phosphorous alloy, and assuming the Armco iron to contain 0.01% C), is $T = 1539.4 - 70.7C$ (f).

(VI) That for all of Andrew and Binnie's observations, up to and including that for 0.71% carbon steel (omitting the high-phosphorous alloy, assuming the Armco iron to contain 0.01% C, and leaving out two alloys of rather high silicon content), is $T = 1538.5 - 61.0C$ (g).

A comparison of equations a, b and c shows how closely the results obtained by Carpenter and Keeling fell in line and leads to the view that the melting point of iron on their scale (on the assumption that Raoult's law holds and that the method of least squares can be applied here for determining the equation for the best straight line) was close to 1508° C.

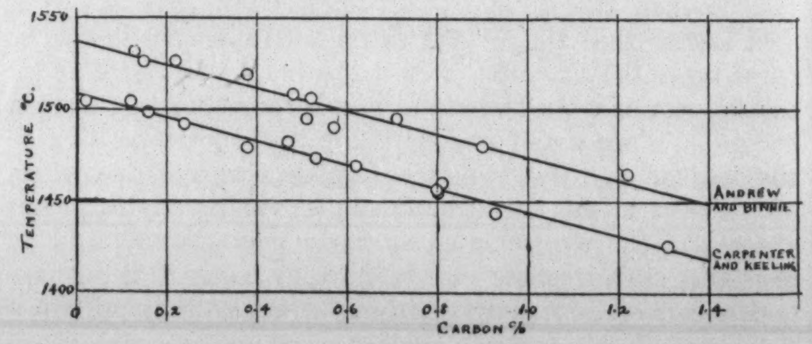

Fig. 1

A comparison of equations d, e, f and g shows that Andrew and Binnie's results did not fall as closely in line as did Carpenter and Keeling's. This, however, is not surprising in view of the fact that the former used commercial steels in their investigations. The melting point of iron on their scale is 1537° C.

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[*] Director of Metallurgical Research, Ontario Research Foundation, Toronto.

[1] *Journal Iron and Steel Institute*, **65**, 224 (1904).

[2] *Journal Iron and Steel Institute*, **78**, 290 (1908).

[3] *Annalen der Physik*, **327**, 251 (1907).

[4] *American Journal Science*, **29**, 93 (1919).

[5] *Bulletin, American Institute of Mining & Metallurgical Engineers*, **153**, 2051 (1919).

[6] Burgess, *Bureau of Standards, Journal of Research*, **1**, 635 (1928).

[7] *Journal Iron and Steel Institute*, **110**, 90 (1924).

[8] *Journal Iron and Steel Institute*, **119**, 309 (1929).

A comparison of equations a and d is of exceptional interest and on this account they are reproduced:

(a) T = 1507.7—63.9 C,
(d) T = 1536.9—62.9 C.

It will be seen that the two lines are so nearly parallel as to admit of being considered absolutely so and 29.2° C. apart. In other words, a correction of +29.2° C. might reasonably be applied to all Carpenter and Keeling's values (for temperatures above about 1426° C.—the liquidus for the 1.3% C steel) in order to bring them into line with Andrew and Binnie's results, and this correction has been applied to those of Carpenter and Keeling's solidus values, 1416° C. and over, in the discussion which follows (see Fig. 2).

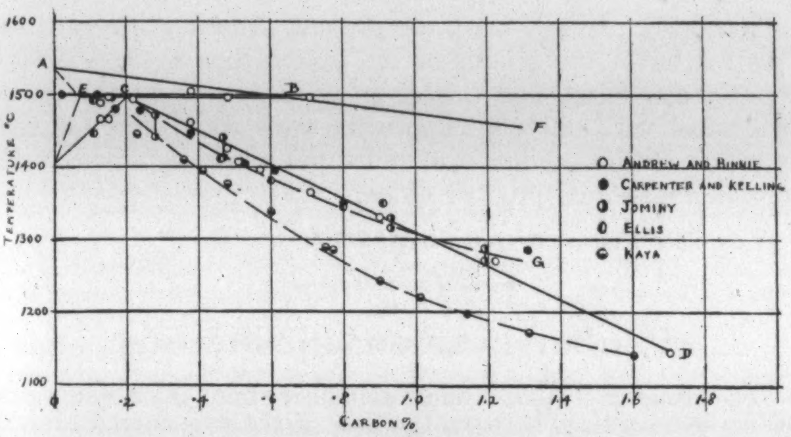

Fig. 2

To return to the discussion of the solidus, concerning which such remarkable differences of opinion exist. Five years after the publication of the Carpenter and Keeling diagram, Gutowsky[9] published a diagram showing a distinctly curved solidus. The curvature of this solidus was confirmed by Rosenhain in 1911, at which time he published a diagram similar to that shown in Fig. 3. Hanson, then of the National Physical Laboratory, discussing this diagram in Glazebrook's *Dictionary of Applied Physics*[10] says: "More recently Rosenhain has plotted the experimental results of Carpenter and Keeling, of Gutowsky, and of himself, and obtained the diagram shown in Fig. 7" (Fig. 3 here). . . . "The special feature of Rosenhain's diagram is the shape of the solidus curve of alloys forming solid solutions. This is based on the work of Gutowsky and of himself, in which the Heycock and Neville quenching method of investigation was used in preference to the ordinary method of thermal curves. It is very probable that the curved form of solidus is very much more accurate than the straight line indicated by most other workers." The upper part of the solidus of Fig. 3 has, of course, been altered as the result of work on the A_4 point[11], but even in Hanson's revised diagram (1923) the curved solidus is retained.

The Japanese workers, Asahara[12], Kaya[13], and Honda and Endo[14], confirm in the main the accuracy of Gutowsky's observations and show a curved solidus in their diagrams. In Fig. 2 the dotted line indicates the solidus due to Kaya, together with the twelve points determined by him. The Ashara and the Honda and Endo solidi differ only slightly in position from that of Kaya.

In Asahara's work the Heycock and Neville method of determining the solidus was adopted. Kaya adopted the electrical resistance method using a Leeds and Northrup potentiometer and lead wires of iron. The resistance was measured at intervals of from 5–7° from a temperature about 200° C. below the solidus. "In order to eliminate the disturbing effect of thermo-electricity, the observations were always made for direct and reversed currents passing through the specimen, and their mean was adopted as the final result"...... "Heating was conducted rapidly till the temperature attained 200° C. below the required degree and then very slowly at the rate of about 150° C. per hr." Honda and Endo used the magnetic method. In their experiments "the furnace was preheated to a suitable temperature and the specimen introduced, then the measurement was commenced at 100–200° C. below the solidus point of the specimen, so that the specimen should not be heated at a high temperature for too long a time." The rate of heating was not referred to in the paper, but it is likely that it was of the same order as in Kaya's experiments.

One would judge from the above that little was to be gained by using the Heycock and Neville method, seeing that almost identical results can be arrived at by the use of methods involving the heating of the specimens at 2° C. per minute—in other words, that equilibrium is reached at every temperature on heating, even though the rate of heating is in excess of 2° C. per minute. This is indeed surprising, since, despite the fact that the resistance and magnetic observations of Kaya and Honda and Endo were made at high temperatures, one would not expect equilibrium to be reached so rapidly as apparently it was, even on heating.

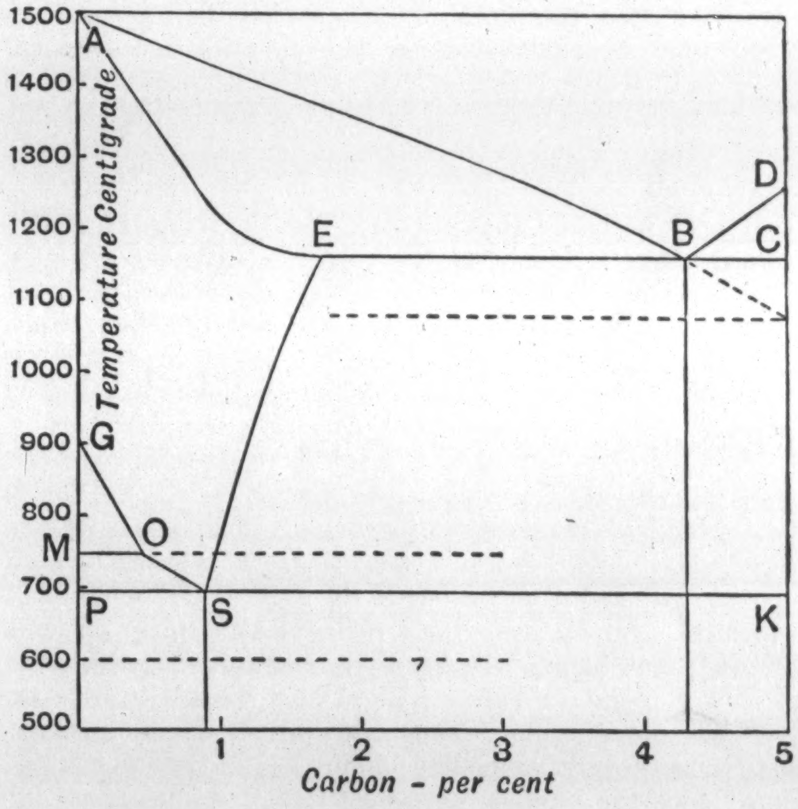

Fig. 3

Turning now to evidence which supports the view that the solidus is straight rather than curved.

In Fig. 2 are shown observations of the solidus by Carpenter and Keeling,[15] *corrected* in the case of steel containing up to 0.38% carbon (solidus—1416° C.) and *uncorrected* for steel of higher carbon content, by Andrew and Binnie[16] by the writer[17], and by Jominy[18]. The values due to Andrew and Binnie were obtained from thermal curves and as a result of electrical resistivity measurements. Those of the writer were obtained by noting the temperature at which the sudden change in the malleability of steel occurs, due to the presence of the liquid phase when the steel is heated above the solidus. The relationship between temperature and malleability was found to be linear in the case of all the straight carbon steels tested by the writer, so long as the steels were austenitic (above the A_3, $A_{3.2}$, or A_{cm} points, or between the A_3 and A_4 points, in the case of steel containing less than about 0.2% C). A marked departure from the straight line relationship, however, occurred when the solidus was passed. To quote from the writer's paper—

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[9] *Metallurgie*, **6**, 731 (1909).
[10] Glazebrook's *Dictionary of Applied Physics*, 5, 333 (1923).
[11] Hanson's diagram, Fig. 4, page 331, Glazebrook's *Dictionary of Applied Physics.*
[12] *Science Reports, Tohoku Imperial University.*
[13] *Science Paper, Institute of Physical & Chemical Research, Tokyo*, **2**, No. 4, 420 (1924).
[14] *Science Reports, Tohoku Imperial University*, **16**, No. 2, 235 (1927).
[15] See reference 1.
[16] See reference 8.
[17] *Carnegie Scholarship Memoirs*, **15**, 195 (1926).
[18] *Transactions, American Society for Steel Treating*, **16**, 272 (1929).

> "The temperatures at which the departure from rectilinearity were first observed in each of the steels tested are recorded below:

Steel Carbon Percent	Temperature of Solidus (° C.)
0.46	1410
0.60	1380
0.80	1345
0.91	1350

> "If allowance be made for the cooling of the samples in their passage from the forging furnace to the anvil, a reduction of the solidus temperature would need to be recorded. This reduction would, of course, be greater for the 0.91% carbon steel, which was in the form of normal $^3/_4''$ samples, than for the lower carbon steels which were in the form of 1″ samples.
>
> "It is of interest, in passing, to note that the solidus temperatures noted above—excepting that given for the hypereutectoid steel—lie on a line which is almost parallel to, though slightly below, the A*a* line of the equilibrium diagram for the carbon–iron system due to Carpenter and Keeling. While it cannot be said that the author's method of determining the solidus is very accurate, there can be no question that the samples were in equilibrium at the time of measurement of their temperatures, and it is obvious that the method could be so improved as to be of use in the accurate determination of the solidus of pure alloys of this and of other systems."

It may be noted that the reduction in temperature discussed above would be at the very most five degrees only. For example, the writer's observation of the peritectic temperature for an 0.11% carbon steel was 1490° C., which is in the close neighborhood of 1495° C., the average peritectic temperature obtained from the observations recorded in Fig. 2.

Jominy's observations were made in connection with his work on the burning and overheating of steel. In Fig. 2, two of Jominy's observations for each of four steels are shown, these being united by a vertical line. The lower of each of these pairs of observations is the highest temperature to which the steel was heated in a reducing atmosphere without burning; the higher, the lowest temperature at which the steel was found to burn. The solidus would lie between these two observations. There can scarcely be any question as to the samples examined by Jominy having been in equilibrium, since the samples were heated "at temperature" for periods of from 15 to 20 minutes.

On the basis of the above observations (Carpenter and Keeling, Ellis, Andrew and Binnie and Jominy) the diagram in Fig. 2 has been prepared. The full lines, AB, ECB and CD, are probably correct in so far as their positions are concerned, though the curved line CG appears to fit the observations on the austenitic solidus rather better than the straight lines CD. That the maximum solubility of carbon in γ-iron is 1.7% seems to have been so well established, however, that the straight line CD is considered the more acceptable. The line AB is felt to be practically unassailable. It has the formula—

$$T = 1536.9 - 62.9C.$$

The line is continued through to F at about 1.3% carbon but, if continued, would not intersect the eutectic line at 4.3% carbon, but at some higher carbon percentage—that is, it must bend over to fulfill the condition that it intersect the eutectic line at the generally accepted eutectic composition.

A comparison of the Kaya solidus with that drawn here (Fig. 2) will serve to emphasize the remarkable discrepancies which exist between the two groups of observations—those of Gutowsky, Rosenhain, Asahara, Kaya and Honda and Endo, and those of Carpenter and Keeling, Ellis, Andrew and Binnie and Jominy. One is impressed, however, by the practical unanimity of the members of each group as to the position of the solidus, and by the fact that the members of both groups have used equilibrium methods in their work and yet are disagreed. The situation is, therefore, worthy of further investigation. Naturally, the writer is disposed to suggest a further investigation of the solidus, using a more refined method of determining the malleability of steel at a series of temperatures than that used by him in the experiments referred to above.[19] Knowing how sharp is the point at which the malleability-temperature relationship suffers its change in the case of steels, he is impressed by the possibilities this method offers in the investigation of the solidus and of the iron-carbon alloys alone, as well as of other alloys, also. In any case, the present situation in regard to the matter of the solidus of the iron–carbon system is distinctly confusing, and further attempt to clarify the same will meet with universal approval, since a knowledge of the position of the solidus is of much practical importance and not of theoretical interest alone.

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[19] *Carnegie Scholarship Memoirs*, **15**, 195 (1926).

Pittsburgh Aeronautic Meeting

The demands of the aeronautical industry upon the metallurgist could be recognized between the lines of the papers read March 12, 1930 before the Symposium on Metal Airplanes at the Pittsburgh Aeronautic Meeting of the Aeronautic Division and Pittsburgh Section of the American Society of Mechanical Engineers, and the Engineering Society of Western Pennsylvania.

Frank W. Caldwell, Chief Engineer, Standard Propeller Company described in considerable detail the development of the drop-forged metal propeller. During 1918 he set out to develop a type of propeller suitable for drop-forging. After considerable experimental work efforts to use steel were abandoned and work was started with an aluminum alloy about 1922. The failures due to fatigue fractures in the threaded connection of the blade in the hub necessitated a change in design of this connection. He emphasized the importance of inspecting the propeller when completed and at regular intervals. The blades are etched in caustic soda and cleaned with nitric acid to permit inspection for cracks and forging defects. To guard against fatigue failure propellers are etched and inspected after each 100 hours of flying.

H. V. Thaden, Vice-President, Pittsburgh Metal Airplane Company, in a paper entitled "Metalizing the Airplane" stated that "probably one of the few opinions unanimously held by members of the aeronautical industry is that the airplane of the future will be all-metal. In fact, it is quite generally agreed that this is the ultimate. It is also interesting to note that prophecies of when this goal will be reached depend on the prophet's knowledge of the success of recent radical departures in metal structural design.

The advantages of metal airplanes generally conceded are: (1) that their life is longer, (2) they can weather outside storage, (3) they are more fire-resistant, (4) their structure is more homogeneous and crash resistant, and (5) they lend themselves more readily to mass-production methods.

There is a definite indication of a gradual trend toward the use of metal by most manufacturers. In some cases, one notes efforts being made merely to change the component wooden parts to metal. In other cases, component sub-assemblies are completely metallized, unit by unit. The latter method is decidedly better than the former but, in the author's opinion, neither method is as satisfactory as going the whole way and metallizing the entire structure.

The problems are not simple and much research and experimentation are essential. The fact that so few really good metal planes exist to-day is proof of this. However, notwithstanding these difficulties, or possibly because of them, numerous minds are at present working on this interesting problem. In Germany several schools of thought have reached quite successful solutions; more recently the French and English have been meeting with successful solutions; and here in America, we find a number of schools of thought just getting under way."

He continued "In these days of intensive research, a metallurgical development might well alter an entire production procedure. Lighter and stronger materials are constantly being developed as well as commercialized.

(*Continued on page 470*)

Correlated Abstract

Dr. Gillett, the editorial staff and specially selected contributors will prepare abstracts reviewing the work recently reported pertaining to certain subjects. These reviews will take into consideration the work of a number of workers. The current literature will be covered in the Abstracts of Current Metallurgical Literature.

The Status of the Double Iron-Carbon Diagram

> *This is one of the series of papers and correlated abstracts relating to parts of the Iron-Carbon diagram which are still in doubt. This is commented upon on the editorial page.*

"One of the fine things of the outlook for the future is that no one will ever exhaust the possibilities of nature and the secrets of nature. So that all we can do is to speculate in certain directions and try to reach more nearly truth in these various fields." Z. JEFFRIES.[1]

It is believed that these words which referred especially to the problem of hardening of metals in general, and the nature of Martensite in particular, are even more applicable to the possibility of formation of a *graphite-austenite* eutectic directly from the melt.

The question of double solidification curves in the equilibrium diagram of iron-carbon alloys is as old as the diagram itself and it is still a matter of dispute to-day whether the graphite can be separated directly from the liquid iron, or is always formed indirectly from the cementite.

Historical Sketch

The first iron-carbon diagram was presented by Richard Mannesmann[2] in 1879. This diagram is shown in Fig. 1*. The second diagram was one published by A. Sauveur[3] in 1896, which showed diagrammatically only the positions of critical points in cooling steels of various carbon contents.

In 1897 and 1899 there were published the first and the second diagrams of Roberts Austen.[4] The following features of this diagram are to be emphasized; eutectic alloy was assumed to be *graphite-iron* eutectic, solid solution was supposed to be the solid solution of carbon in iron, the presence of free cementite was explained by the liberation of this constituent from solid solution.

In 1900 Roozeboom,[5] considering the solidification of carburized iron as closely analogous to the freezing of fused mixtures of salts and of saline solutions generally, and basing it on the principles of the Phase Rule presented a diagram in which the solidus line was shown for the first time. The constituents of the eutectic alloy were supposed to be the solid solution of carbon in iron (called by him Martensite) and graphite. According to Roozeboom graphite was formed on solidification in all alloys containing more than 2% carbon but at 1000° C. This graphite was recombined with iron to produce cementite, which reaction, however, was not completed except in certain cases.

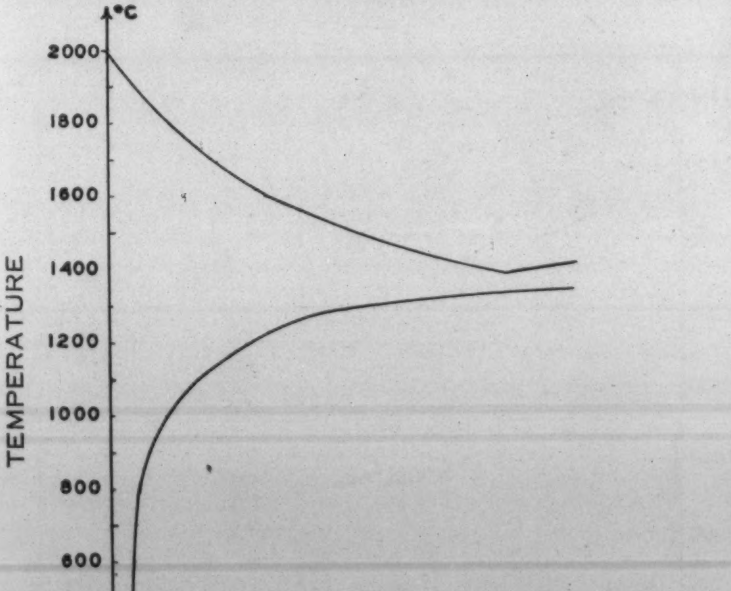

Fig. 1—Diagram Showing the Carbon Solid Solubility in Iron and Also the Melting Points of Carburized Iron
(Published by Reinhard Mannesmann in 1879)

These early ideas, particularly those concerning the nature of the eutectic and solid solution were considerably modified by the later observers.

Various series of experiments led to the conclusion that a final equilibrium is one between the solid phases—ferrite and graphite and several authorities (Le Chatelier,[6] Stansfield,[7] Heyn,[8] Charpy,[9] Benedicks[10]) argued that two equilibrium conditions could exist according to the rate of cooling during solidification, one of them stable, the other metastable.

Stansfield held that in the case of the carburized iron series we have two distinct systems of equilibrium curves: (1) that in which carbon is present in the form of graphite and (2) that in which carbon is present in the form of cementite. We do not know, Stansfield said, at what temperature graphite melts, as Moissan has shown that it volatilizes without any sign of fusion at the highest temperature of the arc, say about 3000° C. His conclusions were that (*a*) carbon is less soluble in iron when presented in the form of graphite than when presented in the form of cementite (*b*) that the apparent reversal of this in steel is due partly to the absence of nuclei or graphite on which further deposits might take place, partly to the length of time required for the separation of the graphite, involving, as it does, the gradual passage of carbon through the iron to reach the nuclei, and partly to the mechanical pressure which must oppose the formation of graphite in solid steel.

Thus it was suggested that two systems, a stable one and a very persistent metastable system should be presented in the diagram.

On this diagram the solidification of free cementite and of the *cementite-austenite eutectic* was assumed to be due to the well-known phenomenon of undercooling; the corresponding curves were arbitrarily drawn at temperatures slightly lower than those pertaining to the formation of free graphite and of *graphite-austenite eutectic.*

This point of view is represented in Fig. 2 taken from the Benedicks' paper.[10]

On the other hand, it was thought that the diagram of the system is of minor importance, since it deals with conditions never met either in the practice or in the laboratory and this point of view probably was best expressed by Howe[11] in his following statement: "our chief reason for taking up the metastable diagram is that it shows us the changes which actually occur in the mechanical and heat treatment of steel, and the temperatures at which they occur and that the topography of this diagram

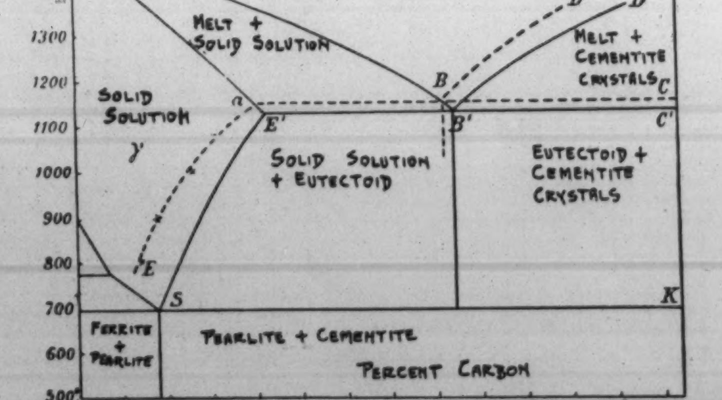

Fig. 2—Double Diagram of Iron-Carbon Alloys
(Published by C. Benedicks in 1906)

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* This diagram differs from Mannesmann's diagram in the respect that the carbon content has been made the abscissa and the temperature the ordinate instead of reverse as in the original diagram.

has been far better explored than that of the graphite-iron diagram."

In order to explain the heat evolution at about 780° C. reported by Carpenter and Keeling and the heat evolution at about 600° C. detected by same authors and Roberts-Austen Upton[11a] in 1908 proposed his equilibrium diagram covering iron-carbon alloys containing up to 10% of carbon, which eliminated the conception of a metastable and stable equilibrium. Upton said, "It was shown by the work of Carpenter and Keeling that there occurred in these alloys (iron-carbon alloys) two new inversions, and, therefore, two new phases, which had been unknown to, or unused by, Roozeboom in his discussion of the relations of iron and carbon. The probable identity of these new phases has been shown, by various methods of approach in each case, to be two new chemical compounds of carbon and iron, Fe_6C and Fe_2C. The temperatures and concentrations of the amplified Roozeboom diagram, including these new phases, have been indicated with a fair amount of accuracy."

According to Upton's diagram, in the hypereutectic alloys there is a direct precipitation of graphite from the liquid, the eutectic point (graphite eutectic) being placed at 1145° C. The presence of the compound Fe_6C was assumed, for certain carbon contents, to be within the temperature range from 1095 to 800° C., while the appearance of the compound Fe_2C was believed to occur at somewhat below 600° C.

It should be pointed out, however, that some years later in his book the same author[11b] adopted a double diagram for this system.

More Recent Data Relating to the Double Diagram of Iron-Carbon Alloys

Passing now to the more recent data relating to this problem it may be stated that the interest in it seems to be more intense now than it was before. This fact undoubtly is connected with the successful attempts to improve the properties of cast iron which for years was considered as the lowest of the ferrous alloys. Probably the most important work in favor of the double diagram of the pure iron-carbon alloys was that of Ruer and F. Goerens,[12] published in 1917. Pig iron containing about 5% carbon was prepared by melting electrolytic iron with sugar carbon. Specimens weighing 20–25 gm. were then melted in a laboratory type (Tammann's) furnace in a nitrogen atmosphere. Very interesting results were obtained by melting specimens, cooling them somewhat below the solidification point (to about 1030° C.), heating them to a certain temperature (about 1160° C.), cooling them again and then repeating these cycles several times. Experimenting with an alloy containing 2.5% C. they found that solidification started at 1342° C. and that the beginning and the end of the crystallization of the eutectic were respectively at 1110 and 1127° C. The specimen which was melted and cooled in the furnace to room temperature showed a white iron structure and contained 2.43% of total carbon and traces (0.02%) of graphite. The specimen which was melted, and cooled to about 1030° C., heated to about 1160° C. and then cooled to room temperature showed the presence of cementite and graphite eutectics. It contained 0.21% of graphite and 2.20% of combined carbon. As it may be seen in Fig. 3 the heating curve (curve 1a) of the first cycle shows only one arrest at about 1146° C., while the heating curve of the second cycle (curve 2a) reveals two thermal arrests, the first and longer one at 1146° C. and the second and shorter at 1153° C. The intensity of both thermal retardations of the heating curve (curve 3a) of the third cycle was found to be almost equal, while in the fourth and following cycles the first thermal arrest of heating curves (at 1146° C.) vanished completely and only the second thermal retardation was present. After ten of such cycles, specimens of this iron possessed a gray iron structure and showed a number of small graphite lamellae arranged in the eutectic-like manner. Similar observations were made on iron-carbon alloys containing $3^1/_2$% carbon and those having 4% carbon.

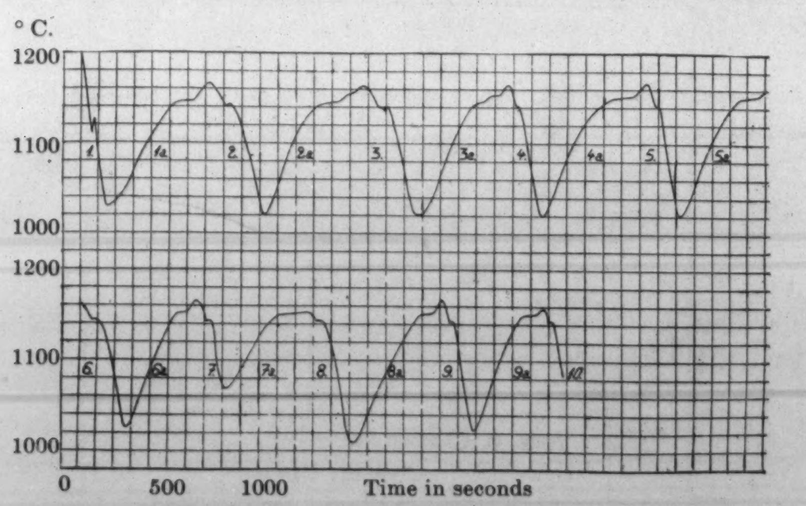

Fig. 3—Curves Representing the Repeated Coolings and Heatings through the Solidification Range of Iron-Carbon Alloy Containing 2.5 % C

(Published by Ruer and F. Goerens in 1917)

Ruer and F. Goerens came to the conclusion, based on these data, that the first thermal arrest of the heating curves was due to the melting of the cementite eutectic, while the second arrest corresponded to the melting point of the graphite eutectic.

The average of the melting and solidification temperature of the cementite eutectic was taken to be 1145° C. while the average for the graphite eutectic was taken as 1152° C. Considering then the results of Gutowsky's[13] investigation on the location of the solidus curve and the data obtained by Ruer and Iliin[14] (Table I), they drew their double diagram (Fig. 4), and determined the location of the iron-carbon eutectoid point at about 740° C. and 0.7% carbon.

Table I—Solution of the Elementary Carbon in Gamma Iron

According to the data obtained by R. Ruer and N. Iliin

Temperature, ° C.	Weight Percent of Elementary Carbon Soluble in Gamma Iron
1120	1.25
1100	1.24
1000	0.99
900	0.84
800	0.75

This figure (0.7% C.) is in full agreement with Guertler's[15] and also with Archer's[16] data. These authors hold that graphitization is completed in passing through Ar_1 (stabile) by the precipitation of an iron-carbon eutectoid containing approximately 0.7% of carbon which is, therefore, located slightly to the left of the iron-cementite eutectoid (pearlite).

It is often held, Merica and Gurevitch[17] stated, that graphitization during cooling from 1100–700° C. is due to the formation of temper carbon from cementite, which has previously precipitated along the A_{cm} line and that graphite itself cannot form directly from the solid solution. According to these authors such a theory of the process is not capable of explaining the phenomena observed by them. They believed that graphite separates directly from solid solution upon cooling, when its nuclei are already present.

Schwartz and his associates[18] went somewhat further and claimed the existence of a solid solution of carbon in iron called by them "Boydenite," which should bear the same relation to the stable system which austenite, in its generic sense, bears to the metastable. Carbon has been shown to have a definite solubility as Boydenite immediately above the A_1 point, the eutectoid concentration in the graphite system being fixed by Schwartz as 0.53% carbon.

These definitions by Schwartz can probably be compared with the terms "normal" and "abnormal" austenite used now by some authors. It may be pointed out also that according to Harder and Johnson[19] the A_{cm} line for the normal steel is parallel to to the line ordinarily shown into the diagram but it should be shifted to the left so that the eutectoid point would come at about 0.75% of carbon instead of 0.9% C. In the abnormal steel the A_{cm} line is shifted still further to the left and if extended would cut the A_1 line at a carbon content of about 0.55% which figure is very close to that one given by Schwartz (0.53% C).

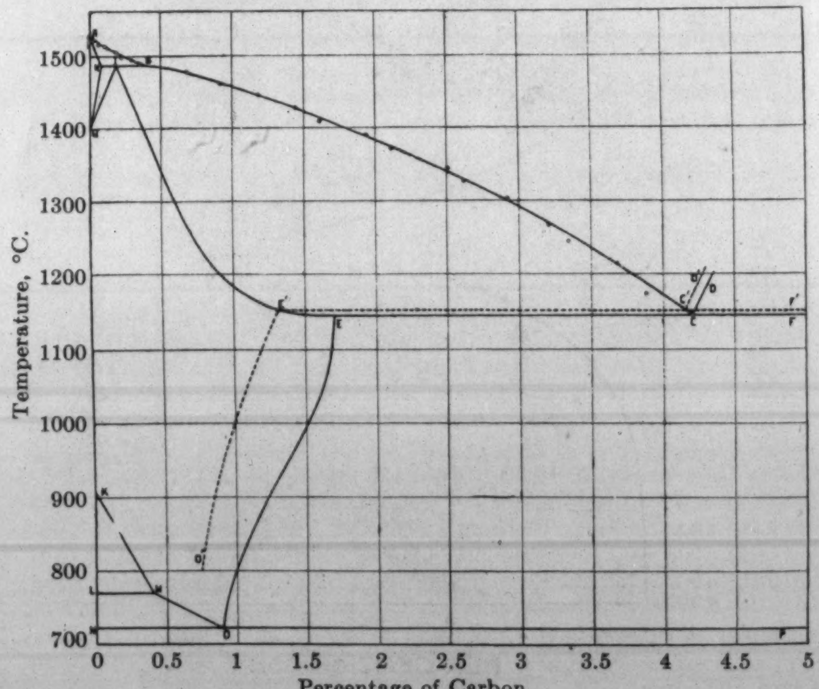

Fig. 4—Double Diagram of the Iron-Carbon Alloys

(Published by Ruer and F. Goerens in 1917)

Iron–Carbon–Silicon System.—After carbon, silicon is probably the most important element in the complex alloy cast iron. The most outstanding work on iron-carbon-silicon alloys is due to Hanson,[20] whose investigation was carried out on alloys containing from 0–2% of silicon and from 0–4% of carbon. All the experiments were carried out in such a manner that the structures observed were considered by the author to represent the true equilibrium of the iron-carbon-silicon alloys. From the cooling curves and results of the microscopic examination the diagrams were drawn. According to Hanson *the eutectic arrest was clearly due to the austenite-graphite eutectic.* It was alleged that this fact was definitely established by microstructures showing clearly the primary austenite grains embedded in a very fine matrix of austenite-graphite eutectic, which structure was similar to that obtained by Piwowarsky in his superheated cast iron. Hanson argued also that no evidence was obtained of the prior formation of the austenite-cementite eutectic; there was one heat evolution on the cooling curves. If graphite were formed only from cementite two heat arrests should be observed, one corresponding to the formation of austenite-cementite eutectic, and the second to the decomposition of the carbide. However, the possibility of graphite forming through cementite was not denied by the author since under certain conditions it has been proven to occur, but in his experiments, he thought, there appeared to be no doubt that graphite separated directly from the liquid as one of the constituents of the eutectic. Thus, the solidification of the alloys investigated by Hanson appeared to take place by separation of austenite and graphite, from the liquid (except where the delta allotrope was found), and the diagram, therefore, could be regarded as representing the system iron–graphite. Hanson's theory is based on the fundamental assumption that the iron–carbide and iron–graphite systems intersect at a certain point of the carbon solid solubility line. The theory accounts for the existence of graphite as a stable form of carbon in high carbon alloys (cast irons), whereas cementite alone is found in low-carbon alloys (steel).

According to Hanson the ordinary cast irons practically all fall within the range of composition in which graphite is the stable form of carbon. Hanson's theory may be regarded as superseding the double diagram theory for the iron-carbon alloys, for it represents the facts relating to equilibrium conditions by means of ternary equilibrium diagrams which are really sections through the ternary equilibrium model. But commercial irons, Hanson said, are not usually in a condition of complete equilibrium, and a double diagram may well be utilized to account for a departure from equilibrium. Such a diagram was constructed by this author in which stable and metastable diagrams were superimposed on one another, crossing at a certain point of the carbon solubility line in gamma iron instead of remaining always one above the other. Thus, at some temperature the system may change from one in which graphite is stable to one in which carbide is stable.

It may be noted that a certain hint on the possible overlapping of two diagrams may be found in the Merica and Gurevich diagram[17] showing the lines of probable graphite and cementite separations, which may intersect at a certain point.

Hanson's theory, Everest[21] stated, is based on accurate scientific experiments and accords well with observed facts connected with commercial cast iron. Considering that the crystallization follows the lines of the graphite system, and no precipitation of graphite occurs after solidification, a combined carbon-silicon diagram was drawn by Hanemann,[22] who discussed conditions prevailing when the combined carbon values lie on this curve, above the curve and below it. The values lie on the curve when the solidification takes place according to conditions of equilibrium and after the solidification no more graphite is rejected, they lie above the curve when the solidification occurs according to the iron–cementite system and the case where the values lie below the curve is the rule for cast iron. Piwowarsky's values, Hanemann stated, when plotted show that solidification took place according to the iron–graphite system because all the values lie below the curve. It was argued that superheating has two opposite effects on the combined carbon content. At first the one effect prevails (increase of the combined carbon content by approaching to the equilibrium), then the other (decrease of the combined carbon content by increasing the fineness of the graphite). Therefore the values will increase at first and then decrease. The values of Meyer,[23] who checked Piwowarsky's results by experiments on a larger scale, lay for the greatest part below the curve. From this it was concluded by Hanemann that the double diagram theory is still valid and that the phenomena of superheating cast iron are correctly explained by it.

Separation of Graphite in the Hypereutectic and Eutectic Irons

Slightly above the melting point [1530[24] – 1535° C.[24a]] pure iron does not appear to dissolve more than 5% carbon. With increase of temperature, however, the saturation point of iron for carbon increases materially. Two diagrams referring to the liquidus of iron-carbon alloys containing more than 5% carbon were suggested[36] simultaneously by Wittorf in Russia and by Ruff in Germany. According to Ruff at some 2200° C. molten iron saturated with carbon contains nearly 10% of that element. At this temperature, Ruff believed, the melt consists of the carbide Fe_2C.

As the temperature increases above 2200° C. the solvent power of iron for carbon decreases, carbon being rejected, probably through the breaking up of some Fe_2C into iron and graphite. At some 2700° C. iron can retain but a little over 7% of carin solution. Wittorf worked out a diagram according to which, from a melt containing some 11% of carbon cooling from some 2400 to 2000° C. the carbide FeC_2 crystallizes out between 2000 and 1700° C. Fe_3C forms through the transformation of some FeC_2 between 1700 and 1350° C. FeC and Fe_4C are formed at the expense of the FeC_2; and below 1350° C. the liquid phase disappears. In view of the great difference existing between these two diagrams it may only be concluded that the region to the right of some 5% carbon is still but little explored.

The excess of carbon is deposited on cooling molten iron in the form of graphite, which separates very readily on account of its

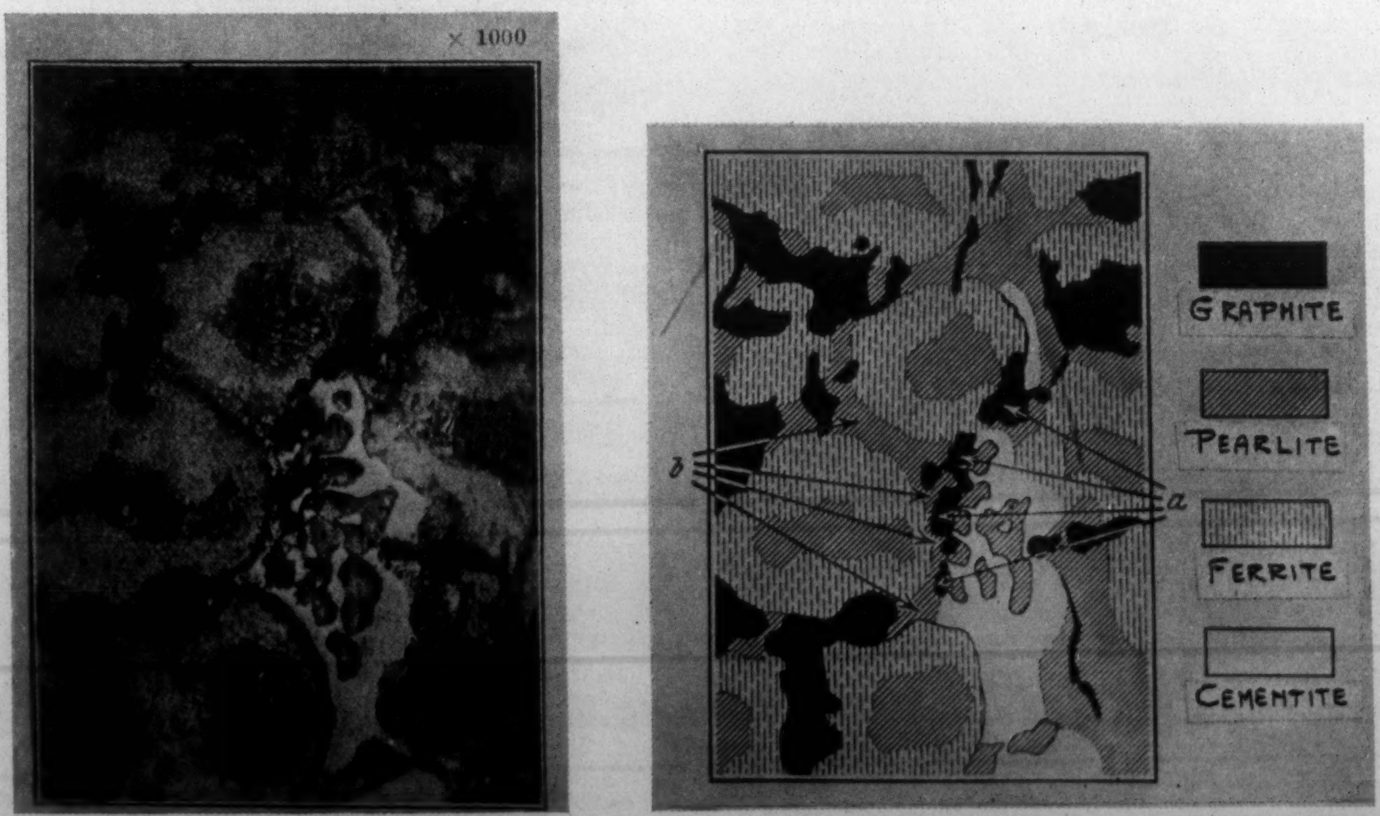

Fig. 5—Micrograph and a Sketch of It Showing the Island of an Eutectic in the State of Disintegration Surrounded by the Primary Crystals of Solid Solution. (Heike and May, 1929)

lightness so that it is difficult to obtain a solid alloy containing more than 6% carbon. The very light, crystalline graphite which collects on the surface of iron rich in carbon is well known in iron works under the name of "kish." P. Goerens[25] presenting his micrograph of a polished specimen of cast iron stated that all kish lamellae were surrounded by a graphite free margin and that finer graphite pseudo-eutectic was at some distance from coarse graphite. He concluded that the primary graphite was evenly distributed throughout the mass of cast iron which fact, he stated, is incompatable with the commonly accepted point of view that the graphite crystallized from the melt must float on the surface. Segregation of graphite in molten cast iron, Pitt[26] stated, is in every way a process analogous to crystallization of salt from a solution. At the point where graphite separation starts, nuclei of graphite first separate, and these nuclei increase by the aggregation of further deposited particles in precisely the same manner as crystal growth proceeds in solutions, the rate of deposition increasing as the temperature falls. Crystallization thus proceeds from individual and isolated nuclei at a regular rate of volume per unit of temperature drop.

Graphite segregating from the liquid can and does grow by the addition of further flakes as they are thrown out of solution just in the manner of crystal growth. A high total-carbon iron will segregate graphite more quickly and in larger quantities as primary graphite.

Primary graphite growing in a liquid or at most very viscous medium at high temperature forms idiomorphic crystals, i. e., crystals, whose outer form is determined by their habit of crystallization, whereas secondary graphite, or temper carbon, forms allotriomorphic crystals, i. e., crystals whose development is hindered by less favorable crystallizing conditions (Schwartz).[18c]

It should be borne in mind that while in pure iron-carbon alloys the eutectic composition is 4.3% carbon, the eutectic lies at about 3.2% when the silicon content is 2 and 2.5% when the silicon content is 4% (Michel).[27a] The carbon outside this eutectic content, Osann [27b] argued, is kish graphite. In the coke blast furnace, kish graphite is segregated in very large quantities. Kish graphite is also present in the free state in foundry pig iron. Every practical foundryman, Osann said, is familiar with the type of pig-iron riddled with cavities, carrying so much kish graphite that it can be removed with a knife. An interesting point of view was expressed by this author,[27c] who believes that internal stress is set up in the casting due to separation of the kish graphite. He considers that the molecules are not in a state of equilibrium, but, like rings under tension, they try to attain this state. If this tension or stress is removed by forcing out the kish graphite crystals, a cast iron exhibiting excellent strength properties is obtained. Thus according to Osann we must strive to get the eutectic composition or we may also say that the liquid iron must be free from kish graphite.

Separation of the graphite in the eutectic form was effected by Schüz[28] who cast iron with a silicon content of over 3% in a chill.

According to Schüz, the germinative power of the primary crystals exercised a great influence on the formation of graphite eutectic. Such a metal could be obtained[28c] in the cupola at 1300° C. with 3% of silicon and 0.02–0.09% of manganese but cooling must be very rapid. A certain illustration of the structure obtained is given in Table II.

State of Carbon in Liquid Iron

In considering the region located above the liquidus line the first question that arises is: in what state is carbon present in the molten metal?

Some, notably Honda,[29] believe that in a molten cast iron carbon is present as cementite molecules Fe_3C whereas others think that carbon is dissolved in a molten iron as elementary carbon. Taking up Schwartz's idea that there are two types of solid solution of carbon in iron, Everest[30] suggested that we may have the carbon in molten cast iron dissolved as carbon or as iron-carbide. There is also a large body of investigators who believe that some amount of graphite can be present in molten iron *per se*.

Piwowarsky,[31] to whom metallurgists are indebted to some extent for the rejuvenation of gray iron in general and for fostering the idea of superheat in particular, believes that the graphite and temper carbon dissolve comparatively slowly in iron and, at least in the early stages, partially as elementary carbon. With increasing degrees of superheat, however, the particles of undissolved graphite present in the melt dissappear more and more and increasing quantities of carbide molecules are probably formed in the melt. At a certain temperature (around 1500° C.) iron carbide dissociates and the process is reversed, the quantity of graphite increasing again.

Postulating his germ theory Hanemann[32] stated that the graphite always occurs in the sheet form if there are graphitic germs present in the molten gray iron. By the term "graphitic germs" it is to be understood that there exist both undissolved small residual particles of graphite from the pig iron employed and also small concentrations of carbon in the molten metal due to an irregular distribution of the dissolved carbon. If one destroys the nuclei by superheating the iron the crystallization of the graphite results in a fine-grained form uniformly distributed throughout the mass. When the iron is jarred[33] the nuclei are mechanically split up and distributed uniformly in the entire melt, thus achieving the same result.

Arguments Against Double Diagram Theory

The double diagram theory always had many opponents. Sauveur, who seemed to be in favor of the austenite-graphite eutectic in 1906[34], some years later argued[36] that if, on very slow cooling, graphite separated directly from molten iron, the bulk of it at least should rise to the top of the molten bath and the solidified mass should be found much richer in graphite near its surface than at some distance from it. On the contrary, on the assumption that graphite results from the breaking up of cementite soon after its solidification, it is readily understood why, in spite of their very great difference in specific gravity, iron and graphite are found uniformly distributed in the various parts of castings. The microscopical examination of the structure of very slowly cooled castings does not reveal the existence of a graphite-austenite eutectic.

W. H. Hatfield in discussing Hanson's paper stated that "he did not believe in the existence of an austenite-graphite eutectic." According to him the initial formation was the austenite-carbide and then the carbide decomposed.

Accepting Schwartz's idea of Boydenite, Bolten[35], however, could not believe that (around the eutectic line) graphite forms directly from the solid solution of carbon or from a graphite-austenite eutectic rather than from cementite. Over more than a ten-year period the double diagram theory of the iron–carbon system was strongly opposed by Honda and his associates. Measuring the change in volume of different cast irons during solidification and comparing the observed and calculated values, Honda and Endo[36] came to the conclusion that the graphite present in cast iron is the decomposition product of cementite, precipitated from the melt at high temperatures. In his recent paper the following points were presented by Honda[29] as additional arguments against the double diagram theory:

(*a*) Many compounds decompose at high temperatures into a simpler form, that is, they have a degree of stability. Cementite has also a certain degree of stability. Hence, if the first precipitation product be always the cementite, but not the graphite, the single diagram must be adopted in spite of the decomposition of cementite at high temperatures.

(*b*) If the decomposition of cementite is really due to the catalytic action of CO or CO_2 gases, the single equilibrium must be a correct one.

(*c*) According to Hamazumi[37], the fine graphite flakes in the form of whorls, which structure is usually considered as an eutectic of graphite and austenite, is a decomposition product of the eutectic between cementite and austenite. The cementite in the eutectic is decomposed just after the solidification, into

Table II—Graphite Eutectic in Cast Iron.*

	Sand Casting			Chill Casting			With Agitation Poured into Water Temperature of which Was as Follows:	
Si, %	Rod 20 Mm. in Diam.	Rod 15 Mm. in Diam.	Rod 10 Mm. in Diam.	Rod 20 Mm. in Diam.	Rod 15 Mm. in Diam.	Rod 10 Mm. in Diam.	35° C.	0° C.
1.9	Graphite flakes	Graphite flakes	Graphite flakes	Graphite flakes + cementite	Cementite	Cementite	Cementite	Cementite
2.5	Graphite flakes	Graphite flakes	Graphite flakes	Graphite flakes + cementite	Graphite flakes + cementite	Cementite	Cementite	Cementite
3.0	Graphite flakes	Graphite flakes	Graphite flakes + small amount of graphite eutectic	Graphite eutectic + small amount of cementite	Graphite eutectic + large amount of cementite	Cementite	Cementite	Cementite
3.5	Graphite flakes	Graphite flakes + small amount of graphite eutectic	Graphite flakes + large amount of graphite eutectic	Pure graphite eutectic	Graphite eutectic + small amount of cementite	Graphite eutectic + large amount of cementite	Cementite + small amount of graphite eutectic	Cementite

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* Schüz E., *Stahl und Eisen*, 45, 144–147(1925).

austenite and graphite; these graphite particles assemble at the grain boundary of austenite by virtue of surface tension and thus form graphite in whorls.

(*d*) When Ruers-Goerens' experiments were repeated by this author and his associates, in a few cases there was observed a two-stepped heat absorption in the heating curve, the difference in temperature being from 3–5° C. This phenomenon was explained by the authors by the difference of the velocity of dissolution of cementite and graphite in iron.

(*e*) Two distinct lines corresponding to cementite and graphite solid solubilities, according to X-ray analysis, cannot theoretically be admissable and if there is only a single cementite solubility line, the graphite lines in the double diagram cannot be completed.

(*f*) If a molten cast iron is rapidly cooled cementite is always found, but no graphite, hence in molten iron carbon is present as cementite molecules, Fe_3C, but not as carbon atoms.

In an extensive discussion based on their recent experimental data Heike and May[38] came to the conclusion that eutectic graphite seems to be a secondary product. This point of view was illustrated by micrographs showing the long straight needles of cementite in their transition state. One of such micrographs and a sketch of it are given in Figs. 4 and 5. One may see an island of an eutectic (Ledeburite) which is in a state of its decomposition. Between the solid solution areas, graphite (*a*) and pearlite (*b*) are present. Thus, according to the authors it appears that cementite is the first one which separates from the melt and that graphite is then formed from cementite according to the following reactions:

1. $Fe_3C \longrightarrow 3\,Fe + C$
2. Fe_3C (undecomposed) $+ Fe \longrightarrow$ solid solution.

The micrographs show further that in every place where graphite was formed, the solid solution lost some of its carbon. This loss in carbon must occur very rapidly for in the immediate neighborhood eutectic was still present. Heike and May believe that graphite in Schüz's eutectic is a secondary product.

Summary

When considering all the discussions above and after reading other papers for and against the double diagram theory one cannot help but ask himself, the question: do we really have enough proof that the single diagram is the only one which represents a true equilibrium condition of the iron-carbon alloys or there still remain some arguments in favor of the double or some other diagrams? Shall we accept as definitely proven that in a molten cast iron carbon is present as cementite molecules Fe_3C, that Ruer-F. Goerens' experiments are to be disposed of, that there is no such a thing as a directly formed austenite-graphite eutectic, that two distinct lines corresponding to cementite and graphite solid solubilities cannot be admissible? It seems significant that in a very recent German handbook of experimental physics[39] the equilibrium condition of the iron–carbon system is represented by the double diagram very similar to that given by Ruer and F. Goerens (Fig. 3). The graphite system in this diagram, however, is shown by a broken line because that system is considered by the author to be indefinite. It may be pointed out that the portion of this German book dealing with this subject was written by P. Goerens who was among the opponents of the double diagram theory.[40]

Jeffries in discussing Honda's paper and, in general, supporting his point of view, did not agree with Honda that in a molten cast iron, carbon is present as cementite molecules, Fe_3C. According to Jeffries, "as melted iron-carbon alloys of certain compositions cool to the solidification range, the carbon atoms are diffused as much as possible, that is, the carbon atoms in the melt are as far apart as they can get. When solidification begins, some of the carbon atoms must get together and there are two ways of combination, one without iron (graphite) and the other with iron (cementite). With iron atoms on all sides of the carbon atoms, cementite may form in accordance with the rule of availability. It is more difficult for the carbon atoms to get together to form the pure carbon or graphite than to combine with a portion of the iron to form cementite."

Here, again, one may note that such a reasoning may hold under the condition that no graphite particles are present in the melt. But in the light of other investigation (Moissan, Stansfield, Piwowarsky, Bardenheuer, Everest etc.) it is very probable that a number of extremely small graphite particles remain in the liquid metal. These particles may be very numerous in spite of their very small total weight, being in a colloidal suspension. When evenly distributed throughout the melt they should serve as nuclei for the carbon segregation.

The higher the maximum temperature of the melt, or the longer the duration of the melting precedure, the smaller the total weight of the graphite and the higher the dispersion of these graphite particles. Finally we reach the condition at which almost all the graphite particles are dissolved in the molten iron.

On the other hand, we know that everything that delays crystallization produces a fine crystalline structure and the term "LABILE" was suggested by Ostwald for the condition of such a degree of supercooling, in which crystallization, when once initiated, extends rapidly throughout the mass with the development of a characteristic "SHOWER" of crystals. At well-defined temperatures the substance is in supersaturation and crystallizes in numerous small crystals, termed the "LABILE SHOWER." The criterion of the supersaturation point, if present, is the appearance of this shower.

In this connection it may be of interest to cite the following experiments of Selivanoff[41] who, while working on the precipitation of crystals of hydrate of lime from saturated solutions, found that this precipitation may be prevented for some time by mechanical means. These crystals usually precipitate very readily from a saturated solution at room temperature, but in his experiments no precipitation was observed after two days of standing at room temperature when the solution was stirred up previously for 12 hours. Thus, such mechanical distortion as stirring may cause a delayed crystallization, which fact is in good agreement with a great improvement observed in the cast iron when liquid metal was jolted for some time before casting.[33]

Applying the supersaturation theory to the iron–carbon system Norbury[42] suggested a new constitutional diagram for cast irons. Instead of one double diagram, he proposed one set of diagrams for the normal condition and another set for the maximum superheating condition. It appears, therefore, that we have now the original single and double diagram theories, compromise theory (Hanson's theory) and supersaturation theory (Norbury's theory), and it seems that the mere existence of several theories on the same question is a good indication that this problem is far from being solved.—A. I. KRYNITSKY.

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Pittsburgh Aeronautic Meeting

(*Continued from page 464*)

"There are to-day three basic materials, or their alloys, in use in commercial aircraft; namely, steel, aluminum and magnesium. Of these, magnesium is still used only to a small extent but its extreme lightness gives it interesting possibilities.

"Magnesium sheet in thin gages presents certain unsolved problems of which fire resistance and corrosion are the most serious. Castings and forgings, however, have a useful field for low-stressed parts such as in secondary members.

"Steel has found extensive uses in aircraft in various classes from the medium carbon to the high alloy. Seamless tubing in both the carbon and in the chrome-molybdenum alloy is used predominately in fuselage structures, and also to some extent in the spars of wing structures. Forgings, where sufficient number of similar parts justify the expenditure for dies, form reliable members for the primary structure. Thin alloy-steel sheet in strip form is used in numerous places as it can be readily formed and welded. The sheet stock or the tubes, when welded and later heat-treated, develop very near their full physical properties, but in the event that length or size make heat treatment, after welding, impracticable, neither the physical qualities nor the fatigue resistance can be realized.

"Aluminum is being used in increasing extent both in the commercially pure state (98%) and in various alloys such as duralumin and alclad. The latter material has particularly good corrosion-resisting qualities because of the coating of pure aluminum with which it is surfaced. Aluminum-alloy tubes, so far, have been commercially obtainable of duralumin only, but it is promised that they will also be made of alclad in the near future.

"Of the aluminum alloys, probably the best known is that of duralumin which contains a small amount of copper. Under proper heat treatment this material finds very extensive use in the primary structure as well as in the covering of an airplane. The fact that it has considerable more bulk for a given weight than steel makes it more resistant to secondary failure such as the crinkling of the free edges.

"Extruded sections of duralumin can be readily formed and offer wide possibilities for mouldings and trim as well as for primary structural members. To date, the minimum practical thickness to which this material can be extruded is about $^1/_{16}$". Duralumin castings can be employed where stiffness or bearing area is required but it seems somewhat hazardous to utilize them for tension members in a primary structure. Duralumin forgings have proved especially practicable and will unquestionably be used to a large extent. One of the advantages of aluminum alloy is the possibility of heat treating the material, subsequently forming and shaping it to size, and still retaining the ultimate physical properties by virtue of its "aging" characteristics.

"Generalizing, it would appear that these various materials could be advantageously used in some of the following ways. For pure tension, the best material from a structural and weight standpoint are the alloy steels. For pure compression, in short columns the magnesium and aluminum alloys offer possibilities except in very highly stressed members. For bending and compression, the limitations of available space for the structure determine the most practical material. In the event that steel is used, the thinness of the material would probably be the criterion, in this event, a bulkier material such as duralumin would work in more efficiently. In fact, the most serious limitation in the use of sheet metal of either duralumin or steel is the inability to use the material in the most economical sizes because of the stiffness factor."

"The discussion of the application of metals to airplane construction was continued by Wellwood E. Beall, Aeronautical Engineer, Walter M. Murphy Company, in his paper "Some Aspects of All Metal Airplane Construction." He pointed out that "Use of metal permits a much closer degree of accuracy. This saves weight. If treated identically, the properties of two runs of metal will be the same, and all parts made from standardized metals and treatments can be counted on to carry the same load and individual tests are not required.

"Of course the problem of corrosion of metals has to be met, and it is believed that if the proper preventatives are made, very little trouble will be experienced from corrosion. Two vital problems in all metal construction are the choice of metals and the type of structure. The metal to use in any part is a function of the type of part, the service for which the part is intended, the strength required, standardization, the weight allowable and the cost allowable. However, even after consideration of the above functions, it is sometimes a rather difficult question. The two metals that seem to have been adopted by the designer, and which have been almost universally used are alloy steel and aluminum alloys.

"In both the United States and England, steel has been used to a great extent, however, in different forms. The English are very favorable to structural members built up of very thin steel strips fabricated into various sections by rivets. Thus, material that has been thoroughly heat treated may be used, and in almost all cases the heat treating is done before fabrication. Stainless steel is also very popular. In the United States the use of steel has been in the medium steels in the form of tubes and in built up fittings, nearly all steel parts being fabricated by welding.

"The use of aluminum alloys is becoming more and more prevalent every day. Several manufacturers both here and abroad are building ships constructed entirely of duralumin with sections made from bent up sheet metal fabricated with rivets. All the problems connected with duralumin have not been solved as yet, but this metal has wonderful possibilities."

New Uses for Bismuth

An important project under way in the metallurgical division of the Bureau of Standards at the present time is a search for new and wider uses for bismuth. The industrial situation with respect to bismuth is a peculiar one. The potential supply of this metal far exceeds the present demands. However, this does not result in any material reduction in price; this is arbitrarily maintained at approximately the same figure which has held for a good many years, and only enough of the purified bismuth is marketed to insure that the current demands will be met. Bismuth is obtained to-day largely as a secondary product in the refining of other metals, notably copper, and large amounts of crude bismuth have accumulated of which no use whatsoever is being made. In other cases no attempt is made to recover the bismuth at all; it is allowed to escape in the stack gases from the smelter. If the present uses of bismuth could be broadened sufficiently or new uses found so as to create a greater demand for the metal, this demand could readily be met and, it is claimed, at a price very considerably below the present market price of bismuth.

This study is being carried out on the research-associate plan in cooperation with the copper-refining industry and has been under way for only a few months. Although bismuth resembles antimony, its sister metal, in many important respects, it is the opposite of ordinary metals in its properties; for example, it expands on freezing. It does not appear from the work done so far that wider uses for bismuth are to be found by substituting it for materials already in use. Utilization of some of the unique properties of the metal will undoubtedly be found to be the answer.

Abstracts of Current Metallurgical Literature

In this section, abstracts of metallurgical articles in various publications will appear. These abstracts are not critical, but merely review developments as they are recorded. Every effort will be made to report on all articles as soon as possible.

GENERAL

Methods in Metallurgical Research. Walter Rosenhain. *Heat Treating & Forging*, Nov. 1929, Vol. 15, pages 1454–1459.

Bibliography of 20 references. Paper before Institute of Metals, Sept. 1929, entitled "Some Methods of Research in Physical Metallurgy." See Metals & Alloys, Jan. 1930, Vol. 1, page 336. MS

How Application of Steel Assists Engineering Advancement. E. F. Kenney. *Iron Trade Review*, Oct. 31, 1929, Vol. 85, pages 1094–1095, 1150.

Part of paper read before American Iron & Steel Institute, Oct. 25, 1929, entitled "Steel's Growing Service to Civilization." See Metals & Alloys, Jan. 1930, Vol. 1, page 336. MS

PROPERTIES OF METALS

Progress in Production and Use of Tantalum. George W. Sears. *American Metal Market*, Feb. 21, 1930, Vol. 37, No. 36, page 5.

Tantalum is receiving increasing attention as an acid-resistant metal. Tantalum ores and production and some alloys are briefly discussed. The extraction and metallurgy of tantalum and of columbium are touched upon. WHB

Unfamiliar Uses Increase Tin Applications. Charles L. Mantell. *Chemical & Metallurgical Engineering*, Sept. 1929, Vol. 36, page 552.

Sn is attacked by inorganic acids, presence of oxygen or oxidizers accelerating the attack. It is not resistant to corrosion by bases or salts. Potassium and sodium dichromates have a passivating action. Pure water has practically no solvent action on pure metal. It is very resistant to atmospheric corrosion and when used as a coating metal, gives excellent protection to base, so long as coating is intact. It is used satisfactorily with oleum, 60% acetic, moist vapors of salicylic acid, tartaric acid, sodium hydrosulphite, caffeine and milk. Pure liquid hydrocyanic acid has no action on pure Sn. Boiling acetic acid over 20% concentration and photographic solutions attack it. MS

Vanadium and Some of Its Industrial Applications. J. Alexander. *Journal Society Chemical Industry*, Sept. 6, 1929, Vol. 48, pages 871–878.

A brief outline is given of the history and chemistry of vanadium and its technical applications, e. g., as an oxidizing catalyst in inorganic and organic preparations, in the manufacture of special steels, and in the manufacture of vanadium-aluminum alloys. These alloys, although only 3% heavier than aluminum, give castings with a tensile strength of 11 tons/in.^{2}, a yield point of 8 tons/in.^{2}, and are said to be unaffected by sea water and atmospheric conditions.—*Abstract Bulletin Kodak Research Laboratories.*

Studies on the Fatigue of Metals. H. F. Moore. *Heat Treating & Forging*, Nov. 1929, Vol. 15, pages 1443–1450. Condensed in *Iron Trade Review*, Oct. 31, 1929, Vol. 85, pages 1098–1099, 1151. *Metal Stampings*, Nov. 1929, Vol. 2, pages 875–876, 900; *Iron Age*, Oct. 31, 1929, Vol. 124, pages 1169–1170; *American Metal Market*, 1929, Vol. 36, pages 11–12; *Iron & Coal Trades Review*, Nov. 22, 1929, Vol. 19, page 802.

Paper read before American Iron & Steel Institute, Oct. 25, 1929 entitled "The Fatigue of Metals—A Review of Progress from 1920 to 1929." See Metals & Alloys, Jan. 1930, Vol. 1, page 336. MS

Correlation of Fatigue and Overstress of Steel. J. H. Smith, C. A. Conner & F. H. Armstrong. *Rolling Mill Journal*, Oct. 1929, Vol. 3, pages 443–444. *Metal Stampings*, Nov. 1929, Vol. 2, page 908.

Abstract of paper read before Iron & Steel Institute, Sept. 1929 entitled "The Correlation of Fatigue and Overstress." See Metals & Alloys, Jan. 1930, Vol. 1, page 337. MS

Precious Metals for Ultimate Corrosion Resistance. Fredric E. Carter. *Chemical & Metallurgical Engineering*, Sept. 1929, Vol. 36, pages 553–555.

The Pt metals and Au resist chemical reagents, have high melting points and are not oxidized. Aqua regia has no effect on Ir, Os, Rh or Rb but dissolves Pt, Pd and Au. Concentrated HNO_3 dissolves Pd and hot concentrated H_2SO_4 attacks Pt slightly but no other single acid has any effect on these metals. Pt alloy is sometimes used instead of Pt in chemical apparatus. The metals are attacked by P, As, Si and C. Caustic alkalis, the alkaline earths and the alkali cyanides attack the Pt metals at a red heat. All the halogens affect them in varying degrees. Au dissolves in potassium or sodium cyanide and in selenic acid. Pt and Rh may be said for all practical purposes to be non-oxidizable at all temperatures while the others oxidize at various high temperatures. The noble metals or their alloys are used for catalysts, electroplating, thermocouples, resistors of electric furnaces, ignition wire in detonating caps, spinnerettes in rayon manufacture and contact points for "making and breaking" electrical circuits. Tabulates the physical properties of the metals. MS

Ultra-Violet Reflecting Power of Aluminum and Several Other Metals. W. W. Coblentz & R. Stair. *Bureau of Standards Journal of Research*, Feb. 1930, Vol. 4, pages 189–193.

In this paper data are presented on the ultra-violet reflecting power of aluminum, duralumin, tin and rhodium. The data on aluminum are of special interest in connection with the use of this metal in reflectors of therapeutic lamps. The results of this investigation show that the ultra-violet reflecting power of aluminum compares favorably with that of chromium (previous investigation, RP39), increasing in reflecting power from about 50% at 300μ to 75% at 550μ. In the visible spectrum, the reflectivity is higher than that of chromium. The ultra-violet spectral reflection of duralumin is similar to that of aluminum. Tin has a fairly high reflecting power and may be useful in certain types of echelette gratings. Mirrors of rhodium are best prepared by cathode sputtering. The reflectivity observed on a polished regulus of rhodium increases from about 30% at 260μ to 45% at 365μ.

PROPERTIES OF NON-FERROUS ALLOYS

New Aluminum and Beryllium Alloys. (Nieuwe Aluminiumalliages en Beryllium.) A. Vosmaer. *Chemisch Weekblad*, March 30, 1929, page 186.

Notes on recent aluminum and beryllium alloys. The high melting point of the latter (1280–1300° C.) as well as the incombustibility, stability, large latent heat of fusion amounting to 277 kg-cal. and high modulus of elasticity are particularly emphasized. EF

How Chemical Industry Applies Copper and Copper Alloys. William H. Bassett. *Chemical & Metallurgical Engineering*, Sept. 1929, Vol. 36, pages 549–551.

Among the Cu materials finding extensive use are deoxidized Cu, red brass, Al-bronze, Tempaloy, Ambrac and Everdur. Cu, deoxidized by the addition of P or some other deoxidizing agent to electrolytic Cu, is used in sugar refineries, soap works, paper and pulp mills, refrigerators and in manufacture of chemicals. Red brass, composed of 85% Cu and 15% Zn shows no tendency toward "corrosion-cracking," to selective attack or disintegration. It is superior to tin bronze in resisting corrosion by most acid and salt solutions and is better than ordinary brass for unusually severe water conditions. Al-bronzes of various compositions are used where strength as well as resistance to corrosion and wear is essential. Tempaloy, patented by Corson in 1928, contains 95% Cu, 4% Ni, 1% Si. When heated to 750–800° C. and then chilled, it is soft and ductile. When heated at 450° C. for several hours, it becomes hard and strong, resembling mild steel in its physical properties. Addition of Al strengthens it considerably and accentuates the hardening properties. Ambrac "A" consists of 75% Cu, 20% Ni, 5% Si and Ambrac "B," 65% Cu, 30% Ni, 5% Zn. They are easily worked and a wide range of physical and mechanical properties may be obtained by suitable treatment. They are resistant to general corrosion and are used with salt solutions, alkaline solutions and dilute H_2SO_4. Everdur, patented by Jacobs in 1925, used in casting is 94.8% Cu, 4% Si, 1.2% Mn. Wrought Everdur is 96% Cu, 3% Si, 1% Mn. It is a corrosion resistant alloy having the strength of mild steel. It resists cold HCl and hot acid up to 20% at 70° C. in absence of air and steam. It is satisfactory with cold 95% H_2SO_4, hot dilute H_2SO_4, mine water where $Fe_2(SO_4)_3$ is absent, and $HC_2H_3O_2$, when air is excluded. Gives some of the physical properties of the various alloys. MS

A Study of Aluminum Bronzes Containing Manganese, Tin and Cobalt. (Étude sur les Cupro au manganese, a l'etain et au cobalt.) Ernest Morlett. *Revue de Metallurgie*, Nov. 1929, Vol. 26, pages 593–605; *Academie des Sciences, Comptes Rendus*, July 8, 1929, Vol. 189, pages 102–104.

The present paper terminates the series (*Revue de Metallurgie*, Sept. 1929, page 464 and Oct. 1929, page 554) and describes the properties of aluminum bronzes with different cobalt content. Six alloys were investigated of the type 90% Cu, 10% Al. In three of them part of Al was replaced with cobalt (0.5%, 2.15% and 3.5%) in the rest cobalt took place of a part of Cu (1.0%, 2.5% and 3.5%). The conclusions for the whole series are summarized. Mn dissolves in alloys composed of alpha and gamma compounds, but does not form any definite compound itself. Its rising content depresses the critical point at 550° corresponding to the eutectic transformation but intensifies the point at 460–490°. Hardness, electrical resistance and e. m. f. grow with the increasing content of Mn. Quenching produces a martensitic structure. Alloys composed of alpha alloy and eutectoid are air hardenable. The addition of Sn deleteriously affects the properties of the metal. Alpha-gamma and alpha eutectoid alloys containing 8.5% Al have acceptable properties with less than 5% Sn. With Al less than 8% and Sn less than 6% the structure consists of alpha-eutectoid in which Sn is kept in solution at room temperature. The critical points are not changed appreciably by Sn addition. Hardness and resistivity grow with it. The alloys can be quenched from 850°. With Al more than 8% (12% max.) and Sn more than 7% quenching shows the same martensitic structure as Cu-Al alloy but the needles observed are quite different from those produced on annealing. Quenching at 900° produces a purely martensitic structure in which is dissolved delta component which precipitates on drawing at 600°. Cobalt does not affect the temperatures of transformation at all. It is soluble in alpha metal up to 1.27% and in alpha-eutectoid metal to 1.66%. Above these amounts it precipitates as needles in alpha alloys and as white crystallites with greyish borders in alloys composed of alpha and eutectoid. At 650° a partial solution and at 900° a complete solution of crystallite is observed in alpha-eutectoid alloy. In pure alpha metal these needles are entirely insoluble. Hardness and resistance grow with the increasing Co content. A bibliography of 15 books is given. JLG

Aluminum Solder. *Brass World*, Nov. 1929, page 276.

"Bull Dog Aluminum Solder" which contains no fluxes, phosphorus, cadmium or bismuth and may be applied in the same manner as ordinary solder to tinned surfaces is marketed by the Marshall Metal Co., 407 E. Pico St., Los Angeles, Cal. The standard grade for aluminum and aluminum alloys melts at 650° F., No. 1 for duralumin, and Grade B for duralumin or aluminum to be subjected to sulphuric acid at 400° F. WHB

PROPERTIES OF FERROUS ALLOYS

Possibilities of High-Strength Cast Iron. E. J. Lowry. *Machinery*, Oct. 1929, pages 162–163; *Translations American Society Steel Treating*, April 1930, Vol. 17, pages 538–562.

Abstract of a paper presented at the convention of the American Society for Steel Treating at Cleveland, Sept. 9–13, 1929. See Metals & Alloys, Jan. 1930, page 337. RHP&WHK

The Mechanical and Metallurgical Properties of Spring Steels as Revealed by Laboratory Tests. H. W. Gillett. Metals & Alloys, Sept. 1929, Vol. 1, page 117.

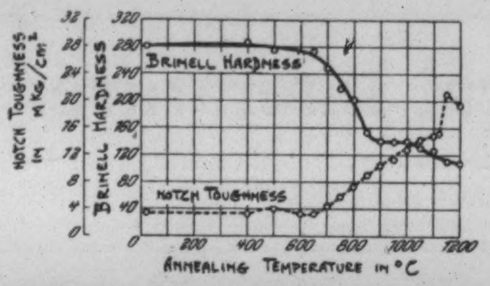
A critical abstract of a paper with the above title read by F. A. Hankins and G. W. Ford before the 1929 spring meeting of the British Iron and Steel Institute.

Chromium Irons and Steels Exhibit Widely Varying Properties. Walter M. Mitchell. *Chemical & Metallurgical Engineering*, Sept. 1929, pages 532–534.

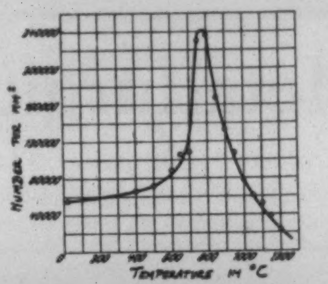
Stainless steels and high-carbon alloys are notable chiefly for hardness and wear-resistance and are useful where such properties are desired. Stainless steels require heat treatment to develop useful physical and chemical properties. Mild stainless steels are notable for high tensile strength and toughness combined with machinability and ductility. They are suitable where these properties are more important than corrosion resistance. Stainless irons have lower strength but higher ductility and corrosion resistance, and are useful where such qualities are of more importance than tensile strength. They do not require heat treatment. Chrome-irons are of greatest importance for heat resistance, and in the higher carbon ranges for resistance to wear and abrasion. MS

Technological and Metallographic Properties of a High Alloy Chromium-Nickel Steel. (Technologische und metallographische Eigenschaften eines hochlegierten Chrom-Nickel-Stahles.) E. Greulich & G. Bedeschi. *Archiv für Eisenhüttenwesen*, Nov. 1929, pages 359–363.

The authors investigated an austenitic nickel-chromium steel of a type which is of increasing importance in the manufacture of turbine blades. The steel with 0.28 C, 0.15 Si, 1.88 Mn, 33.61 Ni and 10.10 Cr was cold-rolled with a reduction of 36.1% after quenching from 1050° C. in water.



Influence of Heat Treatment on the Hardness and Notch-Toughness of Cold Worked, High Alloy Chrome-Nickel Steel



Number of Free Carbides in Relation to the Temperature

The heating of this steel to various temperatures for 2 hours shows that the Brinell hardness decreases beginning with 650° C. The impact strength simultaneously shows a gradual increase. The drop in tensile strength is very marked at 680°. Microscopically a structural change is observed at 600° C. and the first formation of new individual grains at 750° C. The authors counted the grains at temperatures up to 1100° C. and by plotting the grain size on logarithm paper showed that the curve has a hyperbolic shape. Assuming that the formation of new grains begins at the re-crystallization temperature and proceeds through the submicroscopic range according to the same laws as above 750° C. the authors calculate the re-crystallization temperature (665° C.) using the method of least squares. Above 1150° C. the re-crystallization is replaced by a very rapid grain growth, which causes a marked drop of hardness and impact strength and is detrimental to the properties of the material. Furthermore, the occurrence of carbides was investigated. The curve was obtained by plotting the number of carbides against temperature. The convenient and reliable counting of the carbides was made possible by the use of a special selective reagent consisting of a mixture of ammonia persulphate and orthonitrophenol. It was found that the carbides are mainly located along the grain boundaries and slowly increase in number up to a temperature of 700°. Above this temperature they precipitate in abundant quantities in the grains, start to redissolve beyond 800° C. and are in complete solution at 1100 to 1150° C. In this narrow range is the highest toughness. The detrimental influence of the carbides on the properties of these steels is discussed. CK

CORROSION, EROSION, OXIDATION, PASSIVITY AND PROTECTION OF METALS AND ALLOYS

Oxygen's Role in the Electrolytic Corrosion-Testing of Copper and Nickel in Sodium Chloride Solutions. H. W. Gillett. Metals & Alloys, Dec. 1929, Vol. 1, pages 277–278.

A critical abstract of a paper, "The Effect of Oxidizing Conditions on Accelerated Electrolytic Corrosion Tests," by H. S. Rawdon and W. A. Tucker which appeared in *Bureau of Standards, Journal of Research*, Sept. 1929, Vol. 3, pages 375–390.

Testing the Corrosion-Resistance of Alclad. H. S. Rawdon. Metals & Alloys, Nov. 1929, Vol. 1, pages 235–236.

A critical abstract of an article by Erick Rackwitz and Erick K. O. Schmidt appearing in *Korrosion und Metallschutz*, June 1929, pages 130–141.

Metals and Alloys with Resistance to Sulphates and Sulphuric Acid. Pierce D. Schenk. *Chemical & Metallurgical Engineering*, Sept. 1929, pages 575–576.

Pb satisfactorily resists cold H_2SO_4 of all strengths to 95%, and hot H_2SO_4 up to 80% with temperatures up to 205° C. Al bronzes containing Al, 7–11% and Fe, 1–3%, Cu-Si-Mn alloys, high-Ni-Cu alloys, and Ni-Si steels containing Ni 15–35%, and Si 5% are satisfactory for hot weak H_2SO_4 solutions. The bronzes and the Cu-Si-Mn alloys can be used with Al (NH_4) and Ni sulphates, but are unsatisfactory with Ba, Mg, Zn, Cu, nicotine, ferric and mercurous sulphates. The Ni-Cu alloys are excellent for Ni, Zn, Ba and Al sulphates, if no ferric ion is present. Cr-Ni steels of the 18–8 type are not recommended for H_2SO_4 at any strength, but are good for Cu, Al, NH_4, Mg and hot mercurous sulphates. The Ni-Si steels can be used with Al, NH_4, Mg, Ni, Zn and nicotine sulphates. The grade containing 35% Ni is very resistant to ferric and mercurous sulphates. The high-Si irons are very resistant to all strengths and temperatures of H_2SO_4 and to all sulphates. MS

"Durimet." Corrosion-Resistant Steel. *American Machinist*, Oct. 10, 1929, page 647.

Durimet is a product of the Duriron Company, Inc., Dayton, Ohio. They make 3 grades: Durimet A contains 25% nickel, 5% silicon, a trace of chromium and 0.25% carbon; Durimet B contains 35% nickel, 5% silicon, 12% chromium and 0.25% carbon; Durimet D contains 15% nickel, 3% silicon, 2.5% chromium and 0.60% carbon. All grades are austenitic. All are easily welded. All 3 are especially intended to resist corrosion from hot weak solutions of sulphuric acid. Grade B is more resistant than either grade A or D. May be used in construction of pickling tanks. RHP

Effect of Atmospheres on the Heat Treatment of Metals. E. G. de Coriolis & R. J. Cowan. *Industrial & Engineering Chemistry*, Dec. 1929, pages 1164–1168.

A low-carbon steel when heated in an atmosphere containing 6% CO, can be heated to a temperature 100° higher without "burning" than a similar steel heated in an atmosphere containing free oxygen. 6% CO does not eliminate oxidation of metal surface at forging temperatures. It has been determined, however, that by raising the CO content, non-scaling of steel is possible. It has further been proved possible to harden carburized forgings perfectly by retreating in a gas-fired muffle furnace in which a slow current of unburnt city gas is made to pass through the muffle. In tempering or drawing operations, the temperatures are usually sufficiently low to prevent surface and structure changes. The problem of bright-annealing is considered. This is affected by gases evolved when the metal is heated. The use of steam for this purpose is discussed. The effects of lubricants found on metal surfaces present problems in relation to the specific atmosphere in bright-annealing. MEH

Varied Application Characterizes Aluminum in Industry. Paul V. Faragher. *Chemical & Metallurgical Engineering*, Sept. 1929, pages 543–545.

Al, in addition to resisting corrosion by various chemicals, possesses mechanical properties which make it an important construction material in the chemical industries. It is light in weight and can be worked and cast easily. Alloys are often used where strength is a consideration. The addition of the common alloying elements to commercial Al, however, with the exception of Mn, decreases the resistance to corrosion. Alloys containing Si show the best results for castings. Presence of small amounts of foreign substances in the chemicals may alter their normal behavior toward the metal. These effects may be either harmful or beneficial. Gives some specific illustrations of this fact and tabulates the action of various chemicals on Al and its alloys. MS

High-Chromium Cast Steel Flue Becomes Severely Brittle. J. D. Davis. *Chemical & Metallurgical Engineering*, Sept. 1929, page 534.

Note on behavior of cast high-chrome steel during experiments in coal carbonization. Concludes that it is not ideal for service involving alternate heating and cooling in contact with flue gases. Embrittlement may be due to carburization by CO. Resistance to oxidation is very high. MS

The Passivity of Metals and Its Relation to Problems of Corrosion. U. R. Evans. *Technical Publication* No. 205, *American Institute of Mining & Metallurgical Engineers*, 23 pages.

Passivity is due to a protective film or something of that nature. The important role of a scale, film, skin in the phenomena of corrosion is discussed with particular regard to the nature of rust. EF

Protective Value of Chromium. Paul W. C. Strausser. *Metal Cleaning & Finishing*, Sept. 1929, pages 423–426, 431–432.

Describes briefly equipment and operating procedure for chromium plating. A great advantage of chromium is that it will not tarnish. In many cases it will impart hardness, but there is no advantage in chromium plating a non-ferrous base metal to obtain hardness. Under proper conditions, chromium can be well deposited in deep recesses. Defective plate may be caused by improper plating procedure, excessive porosity of the metal coating and too thin a nickel plate beneath the chromium in the case of brass. MS

What the Chemical Engineer Demands of Construction Materials. W. R. Huey. *Chemical & Metallurgical Engineering*, Sept. 1929, pages 522–525.

Materials for chemical equipment should possess superior corrosion resistance and mechanical properties. Lead, iron, copper, nickel, aluminum and their alloys find the widest application. However, each has its faults due either to inferior corrosion resistance or poor mechanical properties. Discusses briefly the peculiarities of these metals and alloys. MS

What Chrome-Nickel Steels Offer to Chemical Engineers. John A. Mathews. *Chemical & Metallurgical Engineering*, Sept. 1929, pages 528–529.

Reviews developments in corrosion-resistant steels. Austenitic chromium-nickel alloys are resistant to chemical corrosion at ordinary temperatures, and to scaling at high temperatures. They possess high strength at elevated temperatures. From the different compositions, a suitable product may be found for almost any requirement in chemical and manufacturing industries where halogen acids are not involved. MS

How Chrome Steels Serve the Nitrocellulose Manufacturer. Thos. McKnight. *Chemical & Metallurgical Engineering*, Sept. 1929, pages 530–531.

Hercules Powder Co. uses chrome steels in equipment for the production of nitric acid by the ammonia oxidation process, and for the handling of strong and weak nitric acid, acidified water and treated nitrocellulose. In general, 18% chromium with carbon below 0.12% is used, although other compositions are used also. MS

Cheaper Low Alloy Steels for Numerous Applications. Jerome Strauss. *Chemical & Metallurgical Engineering*, Sept. 1929, pages 535–536.

Lower alloy steels are of value in chemical engineering when certain mildly corroding mediums are present, when high strength up to 600° C. is required, or when both conditions, combined with good fabrication qualities, are essential. Chrome-vanadium, nickel, or nickel-chrome steels are the most serviceable. MS

Weak Sulphuric Acid Yields to Nickel-Silicon Steels. W. B. Earnshaw. *Chemical & Metallurgical Engineering*, Sept. 1929, page 536.

Crucible Steel Co. of America and the Duriron Co. have developed an austenitic, non-magnetic alloy, which is resistant to hot, weak solutions of H_2SO_4 and possesses excellent physical properties. It has been named Durimet. Rolled grades show ultimate tensile strength of 90,000–110,000 lb./in.², while castings show 75,000 lb./in.² There are three grades, the first containing Ni, 25%, Cr, 0.0% and Si, 5%. The second contains a considerably higher Ni content and a Cr content of about one-third that of the nickel, while the Si is the same. The third grade is made in the form of castings and contains Ni, 15% and lower percentages of Si and Cr. MS

Early Obsolescence May Dictate Common Iron and Steel. E. L. Chappell. *Chemical & Metallurgical Engineering*, Sept. 1929, pages 540–541.

Cast-iron and steel used in the chemical industry may be exposed to corrosion by water and oxygen, high temperature and oxygen and chemicals. Whether it be economical to use special materials costing more but which are more permanent than plain cast-iron and steel, is a problem of economic balance between initial cost and replacement cost. Discusses cases in which the use of common iron and steel is advantageous. MS

New Alloys Withstand Hydrochloric Acid. Burnham E. Field. *Chemical & Metallurgical Engineering*, Sept. 1929, page 542.

Union Carbide & Carbon Research Laboratories have developed alloys made and sold by the Haynes Stellite Co. under the trade name "Hastelloy." The A alloy is a Ni-Mo-Fe alloy of high strength and good ductility which is particularly resistant to HCl. It can be readily worked. The C alloy has a composition which is a modification of that of the A alloy. It is resistant to strong oxidizing agents, more resistant to H_2SO_4 than A and about as resistant to HCl. It must be used in the cast form and is machinable. The D alloy contains an appreciable quantity of Si and small amounts of Al and Cu. It is particularly resistant to H_2SO_4 and quite resistant to HCl. It is strong and tough, makes good castings but is not readily machinable. Presents tables of physical properties. MS

Electro-Deposited Films for Resistant Surfaces. Colin G. Fink *Chemical & Metallurgical Engineering*, Sept. 1929, pages 557–558.

Large-scale commercial electroplating is developing into an exact science because of the development of large-scale plating research carried out to investigate the underlying principles and the protection afforded the base metal underneath from corrosion at a low cost. Electroplating is now a part of the science of electro-chemistry and its principles are adhered to very strictly. Cr is one of the most widely used corrosion-protective metals and Zn and Cd are next in importance. Research will lead to the introduction of base metal parts protected with metal films resistant to the severest kind of corrosion. MS

Stellite for Resistance to Erosion and Abrasion. W. A. Wissler. *Chemical & Metallurgical Engineering*, Sept. 1929, page 558.

Stellite, because of its high degree of red hardness, is being used extensively in many of the large industries where severe abrasion is encountered. It is welded on to an iron or steel base and forms the wear-resisting surface. MS

What Can We Use? W. R. Huey. *Chemical & Metallurgical Engineering*, Sept. 1929, pages 573–575.

Brief discussion of the corrosion-resistant materials which may be used for handling various chemicals. MS

Tantalum—A Metal for Difficult Corrosion Problems. Chester H. Jones. *Chemical & Metallurgical Engineering*, Sept. 1929, page 551.

Ta is used extensively in electrolytic rectifiers and vacuum tubes and as a material for spinnerettes in the production of rayon. It is employed in various kinds of laboratory apparatus because of its corrosion resistance and mechanical strength. As wire, its tensile strength is 130,000 lb./in.². It is inert toward all chemical reagents except hot fused caustic, HF, mixtures of HF and HNO_3 and 95% boiling H_2SO_4. It is easily fabricated. Its principal disadvantage is that it cannot be heated above 350° C. without absorbing gases present and undergoing deterioration. If the metal is used hot it must be in a high vacuum. Presents tables of physical properties of Ta, W, Mo. MS

Durability of Metal Finishes. Ralph F. Cohn. *Metal Cleaning & Finishing,* Aug. 1929, pages 331–334.

The principal causes for the failure of coatings such as electrodeposited metals, paints, lacquers and enamels, may be classified as chemical and mechanical, both of which may be present together. The former includes such conditions as the action of sea water, salt spray, atmospheric impurities and internal reactions within the coating itself, while the latter includes brittleness, wear and sudden changes in temperature. MS

Zinc and Its Alloys Resist Atmospheric Corrosion. William H. Finkelday. *Chemical & Metallurgical Engineering,* Sept. 1929, pages 556–557.

Zn is easily attacked by most common chemicals but develops its greatest resistance to corrosion under ordinary atmospheric conditions. The rolled metal is considerably used for roofings and sidings, but the sheets in the corrugated form are not as strong as galvanized-iron sheets, due to the tendency to flow. New Jersey Zinc Co. has developed a stiff alloy called "Zilloy" by adding Cu, 1% and Mg, 0.01% to Prime Western Zn containing certain percentages of Pb and Cd. Zn is commonly used as a protective coating for iron and steel. For all outdoor and severe indoor service only materials heavily galvanized by the hot-dip process should be used. For semi-protected outdoor and equivalent indoor exposures, sherardized or lightweight hot-dipped coatings are satisfactory. Electro-galvanized coatings are satisfactory for indoor exposures under normal conditions. MS

Where High-Silicon Irons Serve Chemical Industry. *Chemical & Metallurgical Engineering,* Sept. 1929, pages 541–542.

Irons of the composition Si, 14.25–14.50%, C, 0.75–0.85% and Mn, 0.30–0.60% are the most practical products as they possess high acid-resisting properties combined with maximum physical strength. These alloys are practically universal acid resistants. The greatest single difficulty in their use is the tendency to crack with rapid changes in temperature. Their application has been considerably broadened by developments in welding. High-silicon iron is practically unmachinable. MS

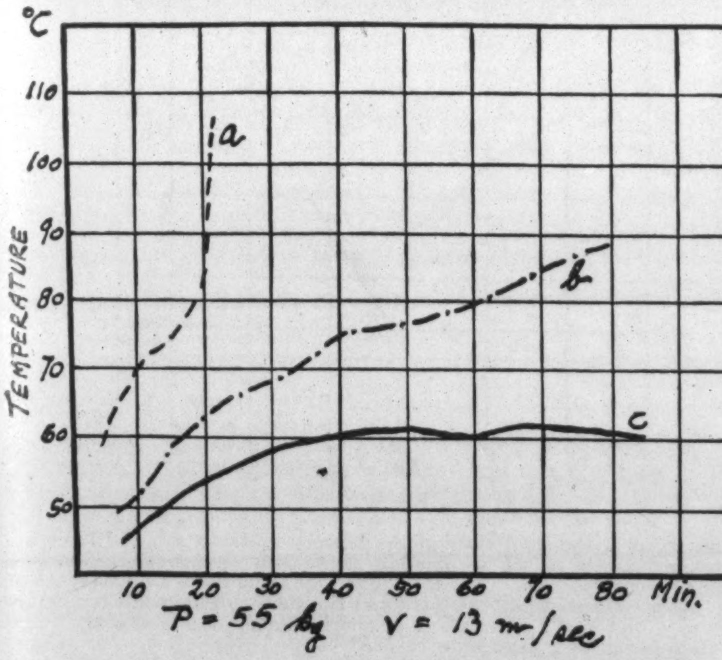
PHYSICAL, MECHANICAL AND MAGNETIC TESTING

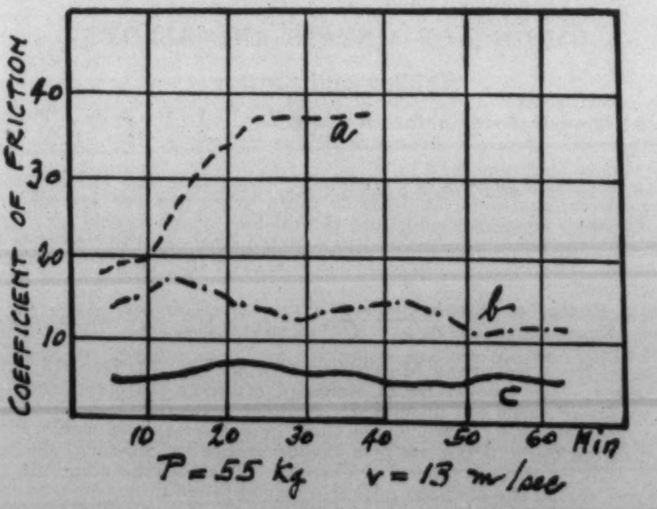
A Synopsis of the Present State of Knowledge of the Hardness and Abrasion Testing of Metals with Special Reference to the Work Done during the Period 1917–27 and a Bibliography. G. A. Hankins. *Proceedings Institution of Mechanical Engineers,* No. 2, May 1929, pages 317–387.

Contains a valuable bibliography of 224 references, pages 353–373. See Metals & Alloys, Dec. 1929, page 289. RHP

Bearing Materials Used in Automobile Construction. (Lagerwerkstoffe im Motorenbau.) M. Armbruster. *Deutsche Motor Zeitschrift,* Oct. 1929, pages 504–506.

Perhaps no part of an automobile engine is neglected more than the materials used in bearing construction. Materials are used without any determination as to their fitness for the purpose applied and the general opinion of bearing materials is that they all operate equally well under variable conditions. To prove the fallacy of the point, the author has selected 3 bearings: alkaline earth lead bearing, a graphitized high lead content bearing and one of high Sn content, lead free. These were tested first under constant pressure and velocity showing time and temperature variations. After 20 minutes the first metal reaches 100° C. while the third is at 55° C. The curve of the third reaches 60° C. in 40 minutes and remains at this point throughout the further increase in time. The second chart compares the coefficient of friction with time. Here, again, the first metal rises rapidly to 47 while the third is practically constant at 5 for all variations of time. The variations in performance are explained by a micrographic analysis explaining the structural and inherent advantages of the third alloy.





So-called "Accelerated" Endurance Testing of Metals with a Review of Ikeda's Method. H. W. Gillett. Metals & Alloys, July 1929, Vol. 1, pages 19–21.

Correlated abstract covering the recent literature on this subject. Comment entitled "A Study of the Ikeda Accelerated Test for Determining Endurance Limit," appeared in Metals & Alloys, Aug. 1929, page 70. A correction to the latter appears in Metals & Alloys, Oct. 1929, page 195.

The Need for Information on Notch Propagation. H. W. Gillett. Metals & Alloys, Sept. 1929, Vol. 1, pages 114–116.

A correlated abstract covering some of the recent literature on fatigue of metals.

Wear Tests on Bearing Bronzes. W. M. Corse. *Iron Age,* Nov. 28, 1929, pages 1431–1434.

A summary of research paper No. 13 of the U. S. Bureau of Standards on "Wear and Mechanical Properties of Railroad Bearing Bronzes at Different Temperatures." Discusses important physical properties of a group of copper-tin-lead alloys within, and in some cases beyond, the limits of chemical composition and constitution ordinarily applied industrially in railroad journal boxes. Two groups of copper tin alloys were studied, i. e., alloys with copper-tin ratio of 92.5 to 7.5 and lead varying from 0.25–25%. The second group with copper-lead ratio of 84 to 16 and tin from a trace to 10%. Two sets of tests were carried on in the presence of oil on a group copper tin-lead alloys. In the first set specimens were subjected to sliding friction under contact pressures. In the second set the alloys were subjected to combined rolling and sliding friction under relatively high contact pressures. Results appear to show that after an initial period in which contact surfaces "wear-in," good bearings will undergo little or no further wear so long as complete lubrication is maintained. Results of tests lead to grouping of bronzes consistent with American Society for Testing Materials tentative specification B 67–27 T. VSP

Bend Testing. H. W. Gillett. Metals & Alloys, Oct. 1929, Vol. 1, page 176.

Brief correlated abstract of two recent papers on this subject.

Recent Work on Fatigue and Corrosion-Fatigue of Steel. H. W. Gillett. Metals & Alloys, Sept. 1929, Vol. 1, pages 116–117.

A correlated abstract reviewing 3 papers dealing with fatigue and corrosion fatigue of steel presented at the meeting of the American Society for Testing Materials.

A New Product of Bearing-Metal Research. *Metal Industry,* London, Nov. 8, 1929, pages 441–442.

Abstract translation of an article in *Technische Blätter,* Aug. 4, 1929, pages 518–519. Discusses a bearing metal known as "Thermit" produced by the Th. Goldschmidt, A.-G. of Essen. Gives results of tests made by various authorities. Considers its casting and uses. Compares its physical properties with that of other bearing metals now in use. VSP

Alternating Strength. (Schwingungfestigkeit.) P. Ludwik. *Zeitschrift des Oesterreichischen Ingenieur & Architektenvereines,* Oct. 11, 1929, pages 403–406.

A wealth of data collected from fatigue bending and fatigue impact tests is given in 7 tables referring to polished test bars grooved in different ways and consisting of non-ferrous metals, cast iron, plain and alloyed steels. EF

Stress-corrosion Cracking of Annealed Brasses. Alan Morris. *Technical Publication* No. 263, *American Institute of Mining & Metallurgical Engineers,* 13 pages.

Annealed brass samples were subjected to tensile stresses while being attacked by ammonia. The time required at a given stress to cause fracture was used as a measure of the stress-corrosion resistance. In alpha brasses coarse grains lowered the resistance while lead and tin increased the resistance slightly. The resistance of Muntz metal and naval brass can be materially increased by quenching from about 500° C. JLG

On Wear of Material under Dry Friction. (Ueber Verschleissbarkeit der Werkstoffe bei trockmer Reibung.) M. Fueschel. *Organ für Fortschritte des Eisenbahnwesens,* Oct. 15, 1929, pages 413–417.

After discussing the various forces of wear as pressure, ~~velo~~city of rolling, temperature, atmospheric oxygen and substances between rail and wheel the author considers the counteracting properties of the material in regard to its surface conditions, mechanical properties, composition, deteriorations, grain and structure. The customary testing methods and machines, especially improvements are reviewed and practical experiences given. EF

Fatigue Tests of Large Specimens. R. E. Peterson. *Heat Treating & Forging,* Aug. 1929, pages 1009–1010, 1013.

Abstract of paper presented before the American Society for Testing Materials, June 24–28, 1929. See Metals & Alloys, Sept. 1929, page 116. MS

Fatigue Tests on Drums and Shells. H. F. Moore. *Journal American Welding Society,* Oct. 1929, Vol. 8, pages 42–52.

Repeated pressure tests were applied to full sized (3 ft. diam.) boiler drums or shells at the Barberton plant of the Babcock & Wilcox Co. Diagram of the repeated-stress apparatus is shown. Seven shells were tested, several to over 400,000 cycles of stress at stresses varying from zero to 50 percent above the allowable working stress. Failures occurred at the tapped hole for gage connection, not in the hand arc-welded seams. Stress concentrations at rivet holes of riveted drums were not as much in evidence as might be expected. Work is being continued. HWG

New Results in the Field of Wear Research. (Neue Ergebnisse auf dem Gebiete der Verschleissforschung.) M. Fink. *Organ für Fortschritte des Eisenbahnwesens,* Oct. 15, 1929, pages 405–412.

The article treats of the phenomenon that in wear experiments, particularly those conducted under rolling friction, an oxidized wear dust is formed Investigations are carried out in gases free from oxygen which, in contrast with former conceptions, proved that this phenomenon does not represent a secondary procedure but is a main factor in wear process. The oxidation component, furthermore, plays a certain role in the formation of the rail grooves. The investigations are performed with an Amsler Testing Machine with steels of various C content, V2A-steel and copper. Theoretical consideration of the problem is given. EF

ELECTRO-CHEMISTRY

Electroplating

Continuous Production in Electroplating. W. Michaelis. *Engineering Progress,* Oct. 1929, pages 259–262.

To secure continuous production in electroplating it is necessary to have complete interaction of the operations. A new automatic machine now makes possible a combined chemical and mechanical pre-treatment process. The "Riedel" ring plating bath is described as to conveying action and current transmission. Gives a table of current densities for various baths. Filters for the electrolyte are described in considerable detail. An installation of the type described has an output equivalent to 12 stationary light nickel baths. RHP

Throwing Power in Chromium Plating. H. L. Farber & W. Blum. *Bureau of Standards, Journal of Research*, Jan. 1930, Vol. 4, pages 27–53; *Metal Cleaning & Finishing*, Sept. 1929, pages 437–438.

During recent years chromium plating has come into extensive use in spite of the fact that it is very difficult to deposit chromium in recesses of irregularly shaped articles. General principles show that in the chromic acid baths used for plating there is little hope of radically improving the "throwing power." The purpose of this investigation was to define those operating conditions which yield the highest throwing power, which at best is poor. The ratio of the weights of metal deposited on two cathodes, one of which is twice as far from a gauze anode as the other, gives a quantitative measure of throwing power. If, under these conditions, as is invariably true in chromium plating, this metal ratio is greater than 2 : 1, the throwing power is negative. The best throwing power obtained was −13%. Under less favorable conditions it was −100% or still poorer. The conditions found to yield the best throwing power are (a) a high temperature such as 55° C. (131° F.); (b) a high current density such as 35 amp./dm.^{2} (325 amp./ft.^{2}); (c) a low concentration of chromic acid such as 150 to 250 g./L (20 to 33 oz./gal.); and (d) a low sulphate content, for example, $CrO_3/SO_4 = 200$. These conditions usually require a potential of over 6 volts. If this is not available, fair throwing power can be obtained in a more concentrated solution with a lower temperature and current density. The numerical results for throwing power are approximately parallel to the covering power, as measured with copper cathodes bent at right angles. MS

Bright Brass and Gold Plating. Joseph E. Underwood. *Metal Cleaning & Finishing*, Oct. 1929, Vol. 1, pages 513–514.

Brightener used in brass plating is made by boiling a solution of 4 oz. NaOH in 1 qt. water and adding 4 oz. As_2O_3. The bath is made by adding 4 oz. NaCN to each gal. of water. $Cu(CN)_2$ is added until a light Cu plates out, then $^1/_2$ oz. $Zn(CN)_2$ per gal. and 2 qt. NH_3 are added. The bath is heated to 110–120° F. and the brightener added a few drops at a time. The following solution is used to produce bright gold deposits: $^3/_4$ oz. $NaAuCl_4$, 6 oz. NaCN, 1 gal. H_2O, at 170–180° F. MS

Much Progress Made in Electroplating. *Iron Age*, Jan. 2, 1930, page 49.

Since the introduction of automatic plating equipment the popularity of chromium and the rust resistance of proper coatings, the electroplating industry has increased. Prior to 1925 about 50 plants were equipped to do plating; now there are over 200 plants capable of plating with nickel, copper, brass, gold, silver, zinc, tin, cadmium and chromium. Heavier nickel base is used for chromium plating. Cost of polishing is still high. VSP

Economies with Automatic Plating Equipment. Floyd T. Taylor. *American Machinist*, Sept. 26, 1929, pages 535–537.

Automatic installations can be used for practically all types of plating, including compound coatings. Less supervision, more rapid production, better and more uniform quality, and savings in plating materials and floor space are shown to be the result of automatic plating machinery. RHP

Lead Alloys for Anodes in Electrolytic Production of Zinc of High Purity. U. C. Tainton, A. G. Taylor & H. P. Ehrlinger. *Technical Publication* No. 221, *American Institute of Mining & Metallurgical Engineers*, 12 pages.

The disadvantages of pure lead as anode material in electrolytic zinc deposition are stated. Investigations with the object of acertaining a more suitable material led to an alloy containing 1% Ag and a small quantity of As. EF

Electrodeposition of Iron. T. P. Thomas. *Metal Cleaning & Finishing*, Sept. 1929, page 464.

Abstract of paper presented before American Electroplaters' Society, July 8–11, 1929. Satisfactory deposits were obtained from a bath containing 40 oz. of ferrous ammonium sulphate per gal., operated at 122–167° F. at a current density of 7 amp./dm.^{2} Used and undersized parts have been built up by this method and have given good service. MS

Use of High Density Copper and Nickel Plating Solutions. Charles H. Proctor. *Metal Cleaning & Finishing*, Sept. 1929, pages 429–431.

For good chromium deposits on steel, it is necessary to have sufficiently thick and tenacious copper and nickel deposits as a base. Gives formulas of the plating solutions to use and operating details. MS

Production of Bright Nickel Deposits. Joseph E. Underwood. *Metal Cleaning & Finishing*, Sept. 1929, pages 435–436.

Glue, gums, etc., as brightners in nickel plating solutions are difficult to control and cause trouble unless small amounts are used. Slight excess causes peeling and cracking. Cadmium salts result in less trouble and the difficulties can be more easily overcome. All brighteners tend to cause hard brittle deposits. Cadmium is best added as the chloride. Gives formulas for the various solutions used. MS

Replating and Polishing of Plumbing Supplies. Edgar L. Tannert. *Metal Cleaning & Finishing*, Aug. 1929, pages 338–340.

Outline of precedure followed in cleaning and plating. MS

Polishing and Plating of Die Castings. Sam Tour. *Metal Cleaning & Finishing*, Sept. 1929, pages 419–420.

Abstract of paper presented before the American Society for Testing Materials, June 24–28, 1929. Polishing and plating properties of die castings are influenced by factors such as the alloy composition, impurities, hardness of the metal, etc. It is often impossible to predict which alloy will present the best surface appearance. This must be found by trial. Impurities such as small quantities of magnesium, oxides and gases have a detrimental effect on the finish of the casting. Soft metal is much harder to polish than hard metal. Copper, nickel and iron improve both polishing and plating properties, while silicon, tin, magnesium and zinc are harmful. MS

Bright Copper Plating. Joseph E. Underwood. *Metal Cleaning & Finishing*, Aug. 1929, pages 355–356.

Bright, adhesive copper deposits may be obtained on antimonial lead surfaces by the addition of salts such as sodium hyposulphite and various soluble lead salts to the plating bath. Lead salts have an advantage in that the plating solution containing them may be used as an electrolytic cleaning solution. Excess of brightening agent in the bath causes a gray deposit and should be avoided. High concentration of carbonate and cyanide causes poor deposits and makes the bath harder to control, and, therefore, an excess of these should also be avoided. MS

What We Do Know About Chromium Plating? Part 2. Methods of Analysis of Chromium Plating Bath for Determining Sulphate, Chromic Acid, Trivalent Chromium, Iron and Copper. Charles H. Proctor. *Metal Cleaning & Finishing*, Aug. 1929, pages 349–352.

Presents details of a procedure which is claimed to be satisfactory, both from the point of view of operations and results. MS

Electrometallurgy

The Electrolytic Preparation of Alloys of Barium and of Strontium. Kenneth W. Ray. Metals & Alloys, Sept. 1929, Vol. 1, pages 112–113.

The introduction reviews briefly the application of the electrolytic method to the preparation of alloys. The purpose of this investigation was to determine what alloys of barium and strontium could best be prepared electrolytically. Various types of apparatus and composition of baths were tested.

STRUCTURE OF METALS AND ALLOYS

Structure and X-ray Analysis

The System Iron–Phosphorus–Carbon. (Ueber das System Eisen–Phosphor–Kohlenstoff.) R. Vogel. *Archiv für Eisenhüttenwesen*, Nov. 1929, pages 369–381.

In the first part of the investigation it is shown that the equilibrium conditions in binary alloys with 10–21% of P are largely dependent on the rate of cooling and the amount of other elements. Correspondingly the crystallization of the compounds Fe_2P and Fe_3P is described. The diagram (Fig. 1) shows the lines of stable and the metastable equilibrium. The point of magnetic transformation is lowered to 720° C. at 1.2% P and then remains constant. In the second part the Fe_3P-Fe_3C section through the ternary system is investigated (Fig. 2). The eutectic line is found at 967° C., the eutectic point at 3.2 C and 8.0 P. The most suitable etching solution for these alloys is a dilute nitric acid containing iron and copper chloride. In the ternary range Fe-Fe_3C-Fe_3P no new phases were found. This range with Fe_3C, Fe_3P, Fe_2P and the 2 solid solutions α and γ containing P besides C and Fe. Due to the transformation points in iron, several transformations can be observed in the solid state of the ternary system; some of them are quite peculiar insofar as we are dealing here with the precipitation and resolution of a crystal type. At 745° the author observed a 4-phase reaction of the α, the γ solid solution, the Fe_3P and the Fe_3C. The result is a disappearance of γ and Fe_3P. The plane of pearlite formation is slightly raised by the phosphorus to a maximum of 745° C. CK

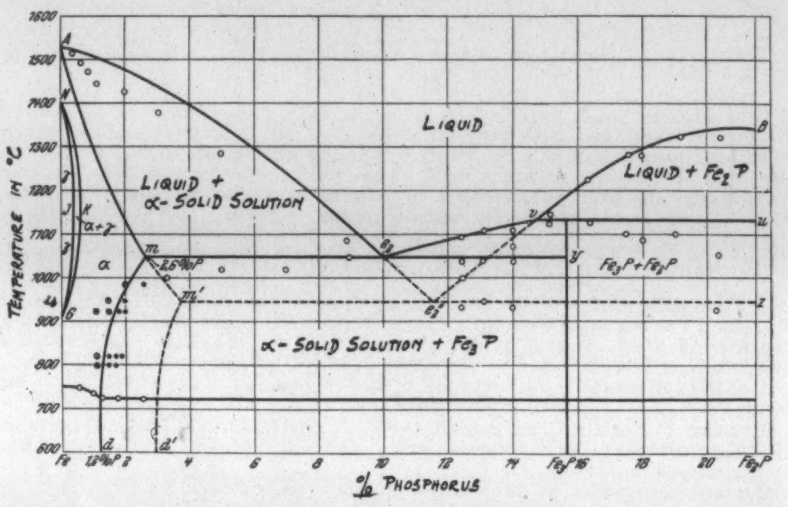


Fig. 1

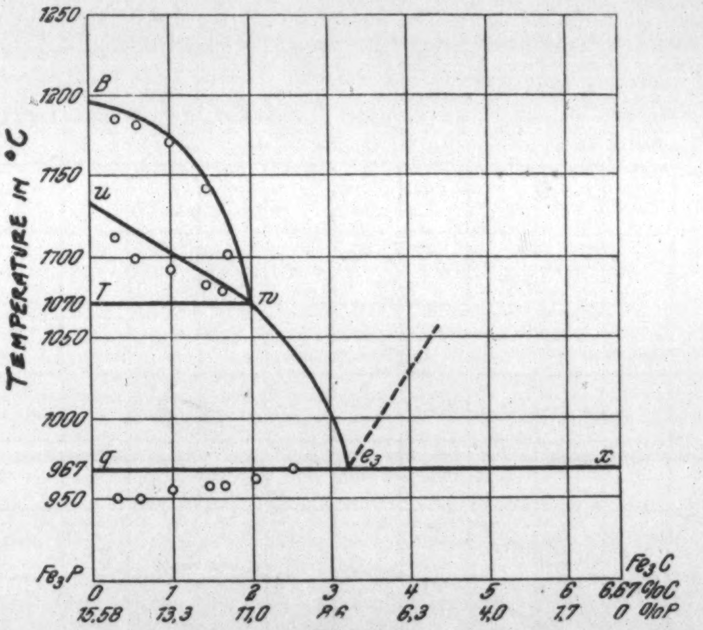


Fig. 2

JOINING OF METALS AND ALLOYS

Welding and Cutting

Material Transference in the Welding Arc. A. Hilpert. Translated by H. Abrams. *Journal American Welding Society*, Dec. 1929, Vol. 8, pages 20–23.

Moving picture exposures of the transfer of metal in the welding arc were taken by special methods, at 1600 or more exposures per second. There are two types of drops formed, one thread-like which tapers off from the electrode end, the other mushroom-like which collects on the electrode before transference. The latter changes its shape greatly in $^1/_{1600}$ sec. The work is being continued. HWG

Welding Rustproof Steels. W. Hoffman. *National Advisory Committee for Aeronautics, Technical Memorandum* No. 531, Sept. 1929, 11 pages, 18 figs.

Translated from Autogene Metallbearbeitung, Vol. 20, Dec. 15, 1927 by D. M. Miner. The properties of welds of ordinary stainless steel and of Austenitic Ni-Cr steels are discussed. Smaller losses of C, Si, Mn, Cr and Ni were found in electric arc welds than in oxy-acetylene welds. A protecting covering on, and the use of a higher proportion of alloying elements in welding rods for the arc process is advised. The alloying elements should be in the rod, not in the coating. Heating a weld in stainless steel to 750° C. for $^1/_2$ hour, and in the Ni-Cr steels to 1200° C., the latter being oil quenched, is advised to secure an approach to uniform hardness. HWG

Application of Electric Arc Welding. Alexander Churchward. *Heat Treating & Forging*, Oct. 1929, Vol. 15, pages 1304–1306.

Reviews recent progress. Molten metal forms globules at the tip of the electrode. Non-ferrous globules are about 10 times as large as the ferrous. A special camera is used to study their formation. MS

Welding of Stainless Materials. H. Bull & L. Johnson. *Technical Memorandum* No. 532, *National Advisory Committee for Aeronautics*, Sept. 1929. 43 pages.

From *Industrial Gases*, March & June, 1928, 30 figs. Includes discussion at meeting of British Acetylene & Welding Association. The air hardening and corrosion resisting properties of stainless steels are discussed. The benefit of the addition of 2 percent Ni to an 18 percent Cr steel is shown. The 18–8 type of austenitic stainless welds better than the ordinary stainless. Heating welds to 1000–1200° C. puts the 18–8 in best condition to resist corrosion. For arc welding it is suggested that the rod contain at least 1% more Cr than is required in the weld. Arc welding rods may be "synthetic," with ferrochromium in the coating, and should be coated with asbestos. For gas welding, the alloys should be in the rod. In discussion, the authors intimated that there was greater loss of Cr in arc welding than in gas welding. HWG

Welding an Aluminum Casting. C. H. S. Tupholme. *Foundry Trade Journal*, Dec. 19, 1929, page 441.

Discusses new method of treating aluminum castings prior to welding. The usual pre-heating furnace is dispensed with. In the new method a steel plate fits the inside of the lid, and is clamped to it along the crack. The whole casting is fastened to a flat surface and the two sides are aligned at the open end by a steel trap. After this, the opening is "veed" carefully. VSP

Large Steel Building Completely Oxy-Acetylene Welded. H. H. Moss. *Journal American Welding Society*, Oct. 1929, Vol. 8, pages 53–63.

Description of gas-welding of steel framing for the research laboratory of the Union Carbide Company, Niagara Falls. The structural steel weighs 10 percent less than that in a riveted job. HWG

Bronze Welding Rod and Its General Use on Metals. P. W. Blair. *Metal Industry*, New York, Jan. 1930, page 21.

Bronze welding rods are used for joining by fusion all types of brass, bronze and copper alloys; also in joining dissimilar metals. Discusses the advantages of bronze welding rods and method of using. VSP

Reclaiming Steel Sharpener Dies by Oxy-Acetylene Welding. M. M. Thomason. *Canadian Mining Journal*, Dec. 20, 1929, page 1211.

Worn steel sharpener dies may be reclaimed by depositing sufficient metal by oxy-acetylene welding to allow machining to the original sizes. In mining circles a special alloy steel welding rod is used to insure the necessary characteristics. WHB

Welding Nomenclature, Definitions and Symbols. Report of American Welding Society Committee on the above. *Journal American Society*, Nov. 1929, Vol. 8, 48 pages.

Definitions of terms used in welding are given. These are clarified, and welding symbols shown, by 142 figs. HWG

Present Status of Welding in the A. S. M. E. Boiler Code. C. W. Obert. *Journal American Welding Society*, Oct. 1929, Vol. 8, pages 72–75.

Proposed revisions of codes for boiler construction and for unfired pressure vessels, and the actions of various states in revising codes are discussed. HWG

Large Gas Line is Arc Welded. A. F. Davis. *Journal American Welding Society*, Oct. 1929, Vol. 8, pages 67–71.

Brief illustrated description of 277 mile, 16 and 18 in. welded pipe line. HWG

Electric Welding of Field Joints of Oil and Gas Pipe Lines. H. C. Price. *Journal American Welding Society*, Oct. 1929, Vol. 8, pages 29–41.

Portable 200 or 300 amp. generators are used for arc welding large pipe in the field. The welding procedure is described. Bell and spigot welds tested by cutting coupons out of actual field-welded joints ran from 41,000 to 56,000 lbs./in.^{2} tensile strength. Efficiency of the welded joints in $12^3/_4$" O. D. pipe, the whole joint being pulled on a tensile machine, ran from 61 to 95 percent. Costs are compared with acetylene welding. HWG

Arc Welded Steel Motor Boats. J. van Horne. *Journal American Welding Society*, Oct. 1929, Vol. 8, pages 25–27.

The U. S. Army Corps of Engineers is building electric arc welded steel motor boats for Mississippi River service. The type of construction is described. HWG

Welded Boilers. E. R. Fish. *Journal American Welding Society*, Dec. 1929, Vol. 8, pages 24–35.

Statement of the problems involved in welding very thick boiler drums for very high pressures. Discussion of published methods of non-destructive testing. HWG

Automatic Arc Welding. W. L. Warner. *Journal American Welding Society*, Dec. 1929, Vol. 8, pages 9–20.

Elementary discussion. Micrographs of welds in bright, deep-drawing steel and in blue annealed steel are shown. HWG

Electrodes for Electric Resistance Welding. F. E. Elge. *Journal American Welding Society*, Oct. 1929, Vol. 8, pages 63–66.

Good electrical conductivity, resistance to deformation under impact, resistance to surface oxidation and to wear, possession of non-magnetic properties, are all important in a resistance welding electrode. Copper has poor resistance to deformation and Cu wheels in seam welders are backed up at the sides by steel. Tungsten-copper alloy is used for points for spot-welding dies, as is chromium-plated copper. For jaws, clamps, etc., aluminum bronze (up to 12% Al, 2 to 4% Fe) though having but 12% of the conductivity of copper are superior because of resistance to deformation. For continuous spot welding dies and fixtures, aluminum bronze without iron is satisfactory. A promising substitute for copper in seam welding electrode wheels is an alloy of copper with 1.8% cobalt, 0.5% silicon, heat-treated. Well-made castings of simple aluminum bronze without addition of iron, titanium or silicon are better for welding-machine use than the complex alloys. HWG

A Contribution to the Study of Influence of Welding Conditions and Subsequent Heat Treatment on the Structure of the Weld. Carl Küttner & J. N. Krivobok. *Journal American Welding Society*, Dec. 1929, Vol. 8, pages 40–62.

Résumé of literature discussing factors in various welding processes that affect the weld structure. Experimental study of resistance and oxyacetylene welds, was made, 19 micrographs being shown. From micrographs taken after heat treatment of the welds, which show incomplete recrystallization because of oxide films or gas absorption, the authors conclude that there is less gas absorption in the resistance method than in the electric arc or oxyacetylene processes. HWG

Rapid Strides Made by Welding. E. E. Thum. *Iron Age*, Jan. 2, 1930 pages 50–52.

Considers pipe welding as a noteworthy achievement. Discusses arc welded and lap welded pipes. Application of welding in structural work. Alloys have been developed that are easily welded. Welding of aluminum alloys of the duralumin type is being investigated. Welded aeroplane fuselage made of chromium-molybdenum tubing has been standardized by the aircraft industry. VSP

Structural Welding Scores Success on Large Western Project. A. W. Lewis. *Journal American Welding Society*, Dec. 1929, Vol. 8, pages 35–39.

Some engineering features of the welded steel work for a large mausoleum. HWG

Welding Copper and High-Copper Alloys. Ira T. Hook. *American Machinist*, Oct. 3, 1929, pages 595–596.

Abstract of a paper presented at the meeting of the American Welding Society, Cleveland, Sept. 9–13, 1929. See Metals & Alloys, Feb. 1930, page 387. RHP

Electrical Welding of Pipe and Tubing for Boilers, Heating, Refrigeration and Other Uses. H. A. Woofter. *Journal American Welding Society*, Oct. 1929, Vol. 8, pages 8–25.

Applications of contact flash welding under high pressure or "push-up," to pipe welding, safe-ending of flues, welding of boiler, refrigerator and other tubes are discussed. Corrosion resistant alloys high in both nickel and chromium are used in tubing for Emmett mercury boilers and for high-pressure (up to 1500 lbs./in.^{2}) special superheat boilers. These require very heavy "push-up in welding, a 2" alloy tube of 0.15" wall thickness requiring as much as a 2" diam. solid carbon steel shaft. Quenching the weld by turning on water from a hose while the weld is in the welding machine is required for some alloys. Field welding of the larger pipe lines by this method is impractical as a 500 k.v.a. portable gasoline motor and electric generator plus an air compressor would be required. HWG

WORKING OF METALS AND ALLOYS

Manufacture of Aluminum Bronze. C. E. Margerum & Lewis H Fawcett. *Heat Treating & Forging*, Sept. 1929, Vol. 15, pages 1164–1166.

United States Naval Gun Factory uses following 2 types extensively: (1) Cu, 88%, Al, 9% and Fe, 3%, which is not generally heat treated for general engineering purposes, and (2) Cu, 87%, Al, 10% and Fe, 3%, in heat treated condition where a hard material is required. Cu is first melted, followed by one-half of the Al, then all of the Fe, and finally remainder of Al. Melting is done in clay-graphite or carborundum crucibles, the metal being covered at all times with charcoal. Metal is teemed into a cast-iron, large end up, ingot mold with sand hot top, to which the shrinkage cavity is confined. The metal is melted only once. The ingot is rough turned, reducing diameter from 1 to 2 in., heated at a moderate rate to 1700° F. and forged with care under heavy presses or hammers. The first type as forged has a yield point of 40,000–50,000 lb./in.^{2}, tensile strength of 85,000–88,000 lb./in.^{2}, and a reduction of area of 33–41.5%. The second type when quenched at 1540–1620° F., and drawn at 700–900° F. had a Scleroscope hardness of 45–50. MS

Red-shortness. (Ein Beitrag zur Frage des Rotbruchs.) A. Niedenthal. *Archiv für das Eisenhüttenwesen*, August 1929, Vol. 3, pages 79–97; also *Stahl und Eisen*, August 22, 1929, Vol. 49, pages 1227–1230.

The author developed a test method to determine the degree of red-shortness. Furthermore, he determined the temperature ranges of decreased plasticity, caused by oxygen or sulphur or by both elements. GN

Melting and Refining

Electrical Cast-Iron Melting Improves Production. G. L. Simpson. *Electrical World*, Feb. 15, 1930, Vol. 95, pages 357–8.

The electric furnace reduces shrinkage difficulties and actual scrap castings and makes it possible to superheat the metal to any desired degree under absolute temperature control. Electric melting also facilitates the control of chill in very small castings.

See Metals & Alloys, Feb. 1930, Vol. 1, page 387. WHB

A Study on Velocity of Reaction and Behavior of Equilibrium in Melting Steel. (En studie över reaktionshastighet och jämviktsforhållanden vid stålmältning.) F Scandelin. *Jernkontorets Annaler*, October 1929, pages 519–544.

The author reviews former publications on the subject, dealing with the theoretical basis of the problem and gives the results of his own investigaions. In investigating the period of refining of three acid open-hearth melts Si: 0.8–1.0%, C: 2.40–2.45%, Mn: 1.17–1.28%, the oxidation of silicon and manganese was found to proceed like a monomolecular reaction, provided the other variables are kept unchanged. Since the concentration of FeO remains constant, it must be concluded that the diffusion of FeO from the easily fusible slag proceeds quickly. The velocity of reaction of these reactions does not progress spontaneously. Oxidation of silicon and manganese are accelerated at higher temperatures and a higher concentration of FeO. But the acceleration of the oxidation process does not proceed in proportion to the temperature but more slowly. GN

The Influence of Wolfram Upon the "Combined Tin" Content of Slags Produced in the Smelting of Cassiterite. K. V. Christie & E. O. Jones. *Bulletin, Institute of Mining & Metallurgy*, Jan. 1930, No. 304, 9 pages and table.

Increasing replacement of silica in the charge by tungstic acid results in an increased loss of tin in the combined form (SnO). Increase in tungstic acid increases slag viscosity, thus increasing prill loss in the slag. Under the experimental conditions, a suitable proportion of reducing agent produced an iron-free tin even when the slag contained 30% or more of FeO. This means either (1) that FeO has a greater affinity than SnO for SiO_2 or (2) that the rate of reduction of SnO to metal is more rapid than the corresponding reduction of FeO, or (3) that oxygen has a greater affinity for iron than for tin ($SnO + Fe \longrightarrow Sn + FeO$). The high tin content of the slag when a pure tin button is produced, the invariable formation of tin-iron alloy and the low tin content of slags when the amount of reducing agent is increased suggests (1) that stannous silicate is not readily reduced by carbon or carbon monoxide or (2) that the removal of tin from the slag is a precipitation process ($Fe + SnO.SiO_2 \longrightarrow Sn + FeO.SiO_2$). High lime content of slags favors lower tin content, probably due to a lower solubility of SnO in calcium silicate than in ferrous silicate. AHE

Sponge Iron, Material for Electric Steel. N. K. G. Thorland. *Blast Furnace & Steel Plant*, Sept. 1929, Vol. 15, pages 1350–1355, 1362.

Paper presented at meeting of American Electrochemical Society at Toronto, May 1929. See Metals & Alloys, July 1929, Vol. 1, page 24. MS

Some Factors in Sponge Iron Production. Edward P. Barrett. *Bureau of Mines*, Serial 2955; *Blast Furnace & Steel Plant*, Nov. 1929, Vol. 17, pages 1659–1660.

See Metals & Alloys, Dec. 1929, Vol. 1, pages 296 and 300. MS

The Influence of Alumina on the Properties of Slags in the Steel Melting Furnaces. (Der Einfluss der Tonerde auf die Eigenschaften der Schlacken in den Stahlschmelzofen.) G. Mars. *Archiv für das Eisenhüttenwesen*, August 1929, Vol. 3, pages 103–116; also *Stahl und Eisen*, September 12, 1929, Vol. 49, pages 1339–1340.

The author compares his results in melting with slags of higher alumina content (the final slag of a melt in a 6 ton electric furnace contained 33.83% Al_2O_3) with those obtained in the generally applied melting manner and states that high alumina slags cause a poor dephosphorization. But on the other hand a good desulphurization and deoxidation can be obtained with alumina slags. The paper also discusses the application of alumina as a refractory material and tests prove that a hearth with 90% CaO and 10% Al_2O_3 gives a good dephosphorization with a pure slag of CaO, as well as an excellent desulphurization and deoxidation. For desulphurization and deoxidation such a hearth seems to be unexcelled for the production of the finest steels. The metallurgical reactions are discussed in detail. GN

Oxides in Pig Iron: Their Origin and Action in the Steel-Making Process. C. H. Herty, Jr., & J. M. Gaines, Jr. *U. S. Bureau of Mines, Bulletin* 308, 1929, 56 pages; *Translations American Institute of Mining & Metallurgical Engineers*, 1929, pages 179–196.

Iron contains its maximum oxide content when a furnace is operating irregularly as shown by the variation in silicon content of the iron or in the tuyère temperature. The elimination of oxides in the open hearth depends upon the size and nature (composition) of the particles, the amounts of dissolved FeO and MnO in the steel, steel temperature, slag viscosity and time for absorption of inclusions by the slag. Additions of ore, cinder or pig iron generally cause an increase in the silicate content of the bath unless the slag will support the lumps of ore or cinder until dissolved. The silicate content of open-hearth steel before deoxidation depends on the silicate content of the charge and chiefly on the silica in the pig iron. Inclusions of this type are most harmful in rolling or forging. The chipping rejections on Bessemer screw stock varied with the silica content of the pig charged. AHE

Casting and Solidification

Reduction of Shrinkage Cavities in Ingots. W. J. P. Rohn. *Rolling Mill Journal*, Nov. 1929, Vol. 3, pages 469–472.

Abstract of paper read before Institute of Metals, Sept. 1929. See Metals & Alloys, Jan. 1930, Vol. 1, page 344. MS

Avoiding Pipes by Casting in Vacuum. (La réduction des retassures et la coulée dans le vide.) W. P. P. Rohn *Revue de Fonderie Moderne*, Oct. 25, 1929, pages 491–497.

Paper before the Annual Meeting of the Institute of Metals, September 1929, Düsseldorf. See Metals & Alloys, Jan. 1930, page 344. GN

Rolling

High-Frequency Coils between Roller Stands for Heating Sheet Metal. *Electrotechnische Zeitschrift*, Aug. 29, 1929, Vol. 50, pages 1273–1274.

In going from one rolling stand to the next, high frequency induction heat is applied to the metal being rolled out. This reduces the number of furnace-reheating operations and eliminates much manual labor.—*Abstract Bulletin Kodak Research Laboratories.*

The Effect of the Rolling in of Tubes on the Qualities of Material and the Stresses in the Tube Plate. (Die Wirking des Einwalzens von Rohren auf die Werkstoffeigenschaften und die Spannungsverhältnisse der Rohrplatte.) E. Siebel. *Mitteilungen Kaiser Wilhelm Institut für Eisenforschung*, 1929, Vol. 11, No. 17 (Report 135), pages 279–285.

The deformations of tube plates were studied. The stresses in rolling in tubes were examined. GN

Forging

Difficulties Encountered in Forging Steels. H. W. McQuaid. *Heat Treating & Forging*, Sept. 1929, Vol. 15, pages 1166–1168; *Blast Furnace & Steel Plant*, Nov. 1929, Vol. 17, pages 1656–1658.

In the manufacture of quality forgings, defects that can be traced to the quality of steel can be classified as (1) forging laps or cold shuts, (2) burnt steel, (3) piped steel, (4) seamy stock and (5) inability to secure satisfactory results in heat treatment. MS

Forging Dies Made by Improved Methods. C. B. Phillips. *Iron Trade Review*, Oct. 10, 1929, Vol. 85, pages 901–903. *Heat Treating & Forging*, Nov. 1929, Vol. 15, pages 1481–1483. *Fuels & Furnaces*, Nov. 1929, Vol. 7, pages 1761–1763.

Studebaker Corp. makes crank-shafts from steel of new analysis and eliminates all heat treatment except normalizing. A new line of dies was developed for this purpose. Practice is to buy die blocks, annealed, cut the impressions, heat treat and finish. Material contains 1.50–1.75% Ni, 0.65–0.75% Cr, 0.40–0.70% C, 0.20–0.50% Mo, 0.40–0.60% Mn and maximum of 0.04% P and S. Dies for large forgings contain low C and Mo, otherwise the high cooling stresses, heavier blows, etc., would cause cracking and chipping. The blocks are heated to 1500° F. at rate of 1″ per hr., quenched in oil or water and drawn at 700–1000° F. The crankshafts are forged to shape from steel containing 0.44–0.49% C, 0.65–0.85% Mn, 0.12–0.20% V, 0.05% S and 0.04% P. They are heated in a continuous automatic, oil-fired normalizing furnace at 1650° F. Cooling from this temperature gives practically same physical properties as are obtained with S.A.E. 1040 steel after heat treatment. MS

Machining

Turning with Shallow Cuts at High Speeds. H. J. French & T. G. Digges. *Bureau of Standards Journal of Research*, Dec. 1929, Vol. 3, pages 829–898.

A method is described for testing lathe tools under shallow cuts and fine feeds. The relations were determined between the cutting speed, feed, depth of cut and tool life for carbon and high-speed tool steels. Comparisons were made of tools of different forms and of tool life when cutting dry and with water or lard oil. Heat treatment and chemical composition of the tools were also studied, including, in the case of high-speed tool steels, the effects of cobalt, nickel, molybdenum, arsenic, antimony, phosphorus, sulphur, copper, tin, aluminum, titanium and tantalum. The results obtained under shallow cuts and fine feeds with these steels are compared with those obtained under heavy duty.

Drawing and Stamping

Galvanizing Sheets for Stampings. Francis G. White. *Metal Stampings*, Sept. 1929, Vol. 2, pages 655–658.

Points out why varying results are sometimes found on forming and stamping galvanizing sheets. Coating has a tendency to peel and manufacturers have produced "tight coats" with reduced amount of coating uniformly distributed. This is a relative term, however, and user should amplify it when ordering sheets. Many failures are due to misinformation of the gage. The Galvanized Sheet Gage is a weight gage, $2^{1}/_{2}$ oz./in.^{2} heavier than the equivalent number of the United States Standard Gage. Size of sheet from which to cut the blank is an important factor. Weight, composition and base are factors affecting adherence of coating. Galvanized sheets can be drawn to considerable depth without peeling, provided the corners are not too sharp and the die clearance is large enough. MS

Influence of the Fillet in Drawing Hollow Bodies from Thin Sheets. (Einfluss der Abrundung beim Ziehen von Hohlkörpern aus dünnen Blechen.) E. Siebel. *Stahl und Eisen*, Nov. 1929, Vol. 49, pages 1731–1732.

E. Siebel summarizes the results of H. Draeger (Berichte über betriebswirtschaftliche Arbeiten, Vol. 2. VDI—Verlag, 1929) on the influence of the fillet in drawing hollow bodies from thin sheets. In investigating the influence of the fillet on the stress in the material, brass sheets (0.30–0.40 mm. thick) and medium hard tinplate (0.25–0.42 mm. thick) were tested. The stresses increased with decreasing fillet of the drawing edge. Furthermore the influence of the fillet on the depth of draw was examined. Under certain test conditions, the depth of draw was calculated and compared with the results of the practical tests. The depth of draw was always found larger than was to be expected according to the calculations. The influence of fillet on the shape of drawn hollow bodies is dealt with. The conditions under which precise cylindrical bodies can be obtained are given. GN

Press Working and Forming of Metals. Part XVI. The Drawing of Cylindrical Shells from Flat Round Blanks. E. V. Crane. *Metal Stampings*, Sept. 1929, Vol. 2, pages 661–669.

Discusses the movements and calculation of stresses in shells caused by deep drawing operations, determination of maximum reduction and drawing and blank holding pressures involved. MS

Causes of Cuppy Wire. W. E. Remmers. *Rolling Mill Journal*, Sept. 1929, Vol. 3, pages 391–392, 394.

Abstract of paper presented at a meeting of the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, in Cleveland, Sept. 12, 1929. See Metals & Alloys, Jan. 1930, Vol. 1, page 344. MS

Pickling

Influence of Pickling Operations on the Properties of Steel. H. Sutton. *Metal Cleaning & Finishing*, Oct. 1929, Vol. 1, pages 535–538.

Abstract of paper read before Iron & Steel Institute, May 1929. See Metals & Alloys, Dec. 1929, Vol. 1, page 292. MS

Cold Working

Effect of Cold Rolling on Physical Properties of Metals. R L. Templin. *Rolling Mill Journal*, Sept. 1929, Vol. 3, pages 393–394.

Abstract of paper presented at a meeting of the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, in Cleveland, Sept. 11, 1929. Slope of curve showing relation between increase in tensile strength and reduction in area by cold working may be considreed as the rate of strain hardening. Relation between yield points and cold working is more complex. Presents curves showing changes by cold working in elongation, yield point, tensile strength, density and conductivity with percent reductuin in area of aluminum. See Metals & Alloys, March 1930, page 430.

Hardness Distribution Produced by ColdcWorking. W. P. Sykes & A. C. Ellsworth. *Rolling Mill Journal*, Ot. 1929, Vol. 3, pages 431–432, 442.

Abstract of paper presented at meeting of the American Society for Steel Treating, Sept. 9–13, 1929 entitled "On the Distribution of Hardness Produced by Cold Working." See Metals & Alloys, Jan. 1930, Vol. 1, page 344; *Iron & Coal Trades Review*, Oct. 25, 1929, pages 626–627.

On Cold and Hot-Working of Austenitic Nickel Steel and Transformer Iron. (Ueber die Kalt und Warmverformung von austenitischem Nickelstahl und Transformatoreneisen.) F. Sauerwald. *Archiv für Eisenhüttenwesen*, Nov. 1929, Vol. 3, pages 365–368.

This article is a further contribution to the question of the limits between the ranges of hot and cold deformation. In previous investigations the author found that for plain carbon steels the range of hot deformation practically begins in the lower range of the γ-solid solution. The present investigation reveals that strain hardening in an austenitic nickel steel (24.6 Ni, 0.72 C) can be observed up to temperatures of 900–1000° C. in the case of rapid deformation In the same range of temperature the 4% silicon steel does not show any strain hardening. Spontaneous crystallizations during deformation are observed in the nickel steel between 900 and 1000°, in silicon steel at 1000° C. Both steels show maxima of strain hardening at 600° and it is suggested that this has a certain relation with the blue brittleness. Koerber and Pomp (Mitteilungen Kaiser-Wilhelm Institut für Eisenforschung, 1925, Vol. 58, pages 105–112) showed that the peculiar behavior of Si steel in the blue brittle range decreases with increasing Si content. The author suggested in previous publications (Zeitschrift für Metallkunde, 1928, Vol. 20, page 408; Sept. 1929, Vol. 21, page 314) the existence of a blue brittle range in nickel. It is now correspondingly concluded that the blue brittleness might be an individual property of the iron atom both in its α and γ-state and of the nickel atom. CK

Cleaning

Process for Degreasing Metals. *Brass World*, Jan 1930, Vol. 26, page 15.

The Carrier Engineering Corp., Newark, N. J. has developed a vapor degreaser of standard dip tank unit type and in a special design adaptable to any size or style of continuous conveyor in line assemblies, and to steam, gas or electric heating. The solvent "Cecolene" is a blanket term for a group of chlorinated solvents, adaptable to various uses and materials. Applications of the device are noted. WHB

DEFECTS

Investigations on Segregation of Ingots from Killed and Rimmed Steel. (Untersuchungen über die Leigerung in beruhigten und nicht beruhigten Flusstahlblöcken.) P. Bardenheuer & C. A. Mueller. *Mitteilungen Kaiser Wilhelm Institut für Eisenforschung*, 1929, Vol. 11, No. 16 (Report 134), pages 273–277.

Two ingots were deoxidised with manganese, a third one with manganese and aluminum. The manganese deoxidised ingots show numerous gas holes all over the cross section, with heavy segregation, whereas the Mn and Al deoxidised ingot is wholly dense with unimportant segregation. The results of the laboratory tests are confirmed in every respect. GN

Comments on Cleanliness of Steel. G. W. Walker & R. E. Sherlock. *Heat Treating & Forging*, Sept. 1929, Vol. 15, page 1176.

Discussion of a paper delivered by R. E. Sherlock before American Iron and Steel Institute and published in Heat Treating & Forging, June 1929. Walker maintains that all dirty steel should be rejected as far as practical limits permit. Sherlock states that rejection should be based on the average size, average amount and uniformity of distribution of the inclusions, as shown in a reasonable number of micro-sections. MS

The Cyanide Bath. V E. Hillman. *Fuels & Furnaces*, Jan. 1929, Vol. 7, pages 31–34.

This does not deal with fatigue failures, but in view of the comment made by Knowlton (Transactions, American Society for Steel Treating, Aug. 14, 1928), appears to be germane. Cyanide-cased, water-quenched steel will snap readily when subjected to stress, although the core, after removal of the case, is satisfactorily ductile. The lack of ductility of the case plus the core is ascribed to intertwining of grains of case and core in the region where carburizing or nitriding ceases in such fashion that a crack started in the case is propagated through the core. See also comment by A. V. deForest (Transactions, American Society for Steel Treating, Feb. 1929, page 212) on work of Gough and Murphy on embrittlement of chain resulting from work-hardening of the surface, a crack starting in the brittle exterior being in this case also continued through the underlying ductile metal.—*From abstracts prepared by the A.S.T.M. Committee on Fatigue of Metals.*

CHEMICAL ANALYSIS

Phosphorus Determination, Iron and Steel. R. P. Hudson. *Blast Furnace & Steel Plant*, Oct. 1929, Vol. 17, pages 1507–1510.

Presents details of practical methods that have been found both convenient and accurate. MS

The Application of Microchemistry to Testing Materials. (Die Mikrochemie im Dienste der Materialprüfung.) F. Feigl. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

A survey of the historical development of microchemistry is given; the advantages which this relatively young chemical science offers for testing materials are discussed. Microchemistry opens new viewpoints and will gain in importance. Results of research of the pioneers in this field, F. Emich and F. Pregl, are presented. GN

Radioactive and Spectroscopic Methods of Microchemistry. (Ueber Radioaktive und spektroskpische Methoden in der Mikrochemie.) F. Paneth. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

The scope of application of radioactive and spectroscopic methods in analyzing microquantities of materials is outlined. According to investigations of Gerlach it is possible to find by spectroscopic methods the location of microimpurities in metals. Examples of the sensibility of spectroscopic methods in analysing gases, quantitative as well as qualitative, are given. GN

Quantitative Inorganic Analysis. (Quantitative anorganische Mikroanalyse.) R. Strebinger. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

The possibilities and importance of the microanalysis when applied to inorganic materials are considered and emphasized. GN

Application of the Spectrographic Analysis. (Die Anwendung der spektorgraphischen Analyse im Eisenhüttenlaboratorium.) K. Kellermann. *Archiv für das Eisenhüttenwesen*, Sept. 1929, Vol. 3, pages 205–211; *Stahl und Eisen*, Oct. 17, 1929, Vol. 49, pages 1520–1521.

Kellermann describes a new spectrographic method with high sensibility which permits the rapid analysis of materials without errors, provided that the element tested is present in an amount not over 1%. The method is especially suitable for laboratories of alloy steel plants. GN

A Gravimetric Method for the Determination of Ruthenium. Raleigh Gilchrist. *Bureau of Standards Journal of Research*, Dec. 1929, Vol. 3, pages 993–1004.

A gravimetric procedure for the accurate determination of ruthenium by hydrolytic precipitation from chloride solution has been developed. A delicate test for the qualitative detection of small quantities of ruthenium, using thiourea as a reagent, is described.

Conductivity Cells and Dipping Electrodes of Brominated Pure Silver in Place of Platinum. W. A. Roth. *Zeitschrift für Elektrochemie*, Nov. 1927, Vol. 33, pages 508–511.

Roth described the method of preparation and the uses of silver-silver bromide electrodes in place of platinum electrodes.—*Abstract Bulletin Kodak Research Laboratories.*

Separation and Determination of Arsenic. B. S. Evans. *Analyst*, Sept. 1929, Vol. 54, pages 523–535.

Modifications in the technic of determining arsenic by precipitation by hypophosphorous acid reduction and titration of the precipitate with standard iodine.—*Abstract Bulletin Kodak Research Laboratories.*

Volumetric Determination of Mercury. H. B. Dunnicliff & H. D. Suri. *Analyst*, July 1929, pages 405–410.

Mercuric chloride is reduced by means of a neutral stannous tartrate solution and the solution filtered. To an aloquot portion an excess of a hot solution of standard ferric alum is added, the excess being back titrated by means of titanous chloride.—*Abstract Bulletin Kodak Research Laboratories.*

ECONOMIC

Electrochemical Industry in Norway. (L'industrie electrochimique en Norvege.) *Journal du Four Electrique*, Oct. 1929, Vol. 38, page 336.

A brief summary for the first quarter of 1929. JDG

Mineral Resources of the United States in 1928 (Preliminary Summary). Frank J. Katz & Martha B. Clark. *U. S. Bureau of Mines*, Sept. 1929, 116 pages.

The total value of all mineral products in 1928 ($5,400,000,000) was 2% less than 1927 and 13% less than 1926. Production of mineral fuels as a group decreased 5.5% in value. Natural gas production increased. Petroleum production decreased slightly although domestic demand increased. Gasoline production increased markedly. The quantity and value of production of bituminous coal and anthracite decreased. The total value of the metallic products of the mines of the U. S. in 1928 was about 5% greater than in 1927 but was well below the value in 1926. Copper, iron and aluminum accounted for the gain. The increase in aluminum production was large, and despite a decline in price, the total value increased 22%. A new record was established by the total refined copper output of the U. S. in 1928 and a new peace-time record by the smelter output. Lessened demand for lead was reflected in a price drop and decrease in production. The price of zinc averaged less in 1928 than 1927, but had an upward trend. Production was steady and of greater aggregate amount, although less value, than in 1927. The production of steel in 1928 reached a new peak, but the production of pig iron and iron ore, although larger than in 1927, was considerably below the record years. Production and value of manganese ore increased slightly. Stimulated by high prices, mercury gained 49% in quantity and 56% in value. Gold production remained virtually unchanged. Silver production decreased sharply, although increased prices made the decline in total value moderate. The total value of non-metallic mineral products (not including fuels) in 1928 decreased moderately as the result of a general decline in prices which offset prevailing increases in quantity of production. AHE

Gold, Silver, Copper, Lead and Zinc in Arizona in 1927. Mine Report. C. N. Gerry. *Bureau of Mines, Mineral Resources of the United States*, 1927, Part I, Sept. 9, 1929, pages 731–744.

The output of gold, silver, copper, lead and zinc from Arizona in 1927 was valued at $98,790,957, a decrease of $14,745,331 from 1926. The average value of the metals recovered from the ore, old tailings, slag, etc., decreased from $5.06 a ton in 1926 to $4.47 in 1927 and the average value in gold and silver from 42 to 36 cents a ton. From 1918 to 1927 most of the gold recovered was about evenly divided between (1) dry and siliceous ore and (2) copper ore. Gold from siliceous ore has decreased, so that in 1927 it was about 1/5 that in 1918. Gold from copper ore has increased; in 1927 it was 47% greater than in 1918. Gold was also saved from lead ore and mixed ores. Very little came from placers. Silver had its chief source in copper ore during the period with lesser amounts from siliceous and lead ores. Production of these metals in Arizona in 1927 decreased from 1926 as follows: gold, 14% silver, 7%; copper, 5.7%; lead, 15%; and zinc, 82%. AHE

Gold, Silver, Copper, Lead and Zinc in Utah in 1927. Mine Report. C. N. Gerry. *Burean of Mines, Mineral Resources of the United States*, 1927, Part I, Aug. 12, 1929, pages 637–676.

The output of gold, silver, copper, lead and zinc from Utah Mines in 1927 was valued at $73,626,632. The decrease of $9,036,252 from 1926 was due chiefly to lower metal prices. The output of silver and copper decreased (4% and slight decreases, respectively) while gold, lead and zinc production increased (6, 2 and 4%, respectively). Utah occupied the following relative position among the states in the production of these metals: silver, first; copper and lead, second: zinc, fifth; and gold, sixth. AHE

Regarding Rumors about Increased Production of Aluminum in Italy, Germany and Norway. (A propos des bruits d'augmentation de production d'aluminium en Italie, en Allemagne et en Norvege.) *Journal du Four Electrique*, Dec. 1929, Vol. 38, page 414.

Critical review of an article in Giornale d'Italia about the 100,000 tons increase in aluminum production using leucite deposits of Italy. JDG

The Future of Electrochemical Industry in the Alps. (L'avenir d'electrochimie dans les Alpes.) *Journal du Four Electrique*, Nov. 1929, Vol. 38, pages 365–367.

Some speculations in regard to the possible expansion of electrochemical industries in the Alpine regions. JDG

Summarized Data of Gold Production. Robert H. Ridgway, *et al* *U. S. Bureau of Mines Economic Paper* No. 6, 1929, 63 pages.

From 1493 to 1927, inclusive, world production of gold has only slightly exceeded a billion ounces. More than half of the total was produced in the first 27 years of the present century. Detailed figures by countries and years from 1493 to 1927 are given in a large folded table. AHE

PLANTS AND LABORATORIES

New Alloys Plant. W. M. G. *Canadian Mining Journal*, Feb. 14, 1930, Vol. 51, page 156.

At the Sault Ste. Marie plant of the Superior Alloys, Ltd., a 2000-kw. capacity ferro-silicon furnace has been placed in operation. Another furnace for lower grades of ferro-silicon is to be installed immediately and later in the year a third furnace of 5000-kw. capacity, for an unannounced purpose. A small furnace for the manufacture of calcium molybdate will soon be in operation. Calcium molybdate is largely superceding ferro-molybdenum for making molybdenum steel. The molybdenite concentrate is roasted to a sulphur-free oxide which is then melted with quicklime to give calcium molybdate. WHB

A Modern British Chromium Plating Equipment. A. Eyles. *Brass World*, Jan. 1930, Vol. 26, pages 1–3.

A brief illustrated description of the chromium plating plant of Mess. Morris Motors, Ltd., Birmingham, England. The plant is designed primarily for chromium plating radiator shells and small automobile fittings and consists of a fully automatic nickel plating plant and a chrome plant for dealing with the same quantity of work. WHB

Forging and Treating Parts for the Nash. Charles Longenecker *Heat Treating & Forging*, Sept. 1929, Vol. 15, pages 1157–1159, 1242.

Describes equipment and procedure employed at the Kenosha plant of the Nash Motors Co. MS

FOUNDRY PRACTICE AND APPLIANCES

The Cupola and Its Chief Dimensions. (Der Kupolofen und seine Hauptabmessungen.) L. Schmidt. *Giesserei-Zeitung*, Oct. 15, 1929, pages 567–577.

The author considers the cupola in connection with the metallurgical reactions and describes the rules to be taken into consideration for its successful operation. The errors which occur in measuring cross-section and height of the stack, cross section of tuyères and capacity of blowers are especially emphasized. Cupolas with large output are generally operated in Germany as well as in America with insufficient blowers. New designs of blowers and regulating instruments are described. GN

Qualities of Combustion of Coke and the Cupola Practice. (Koksverbrennlichkeit und Kupolofenbetrieb.) T. Gwosdz. *Giesserei-Zeitung*, Oct. 15, 1929, pages 578–582.

The article gives the different opinions on the reactivity of coke and discusses the question of whether coke with high combustibility offers advantages in cupola practice. The author sees no advantage in using this kind of a coke. GN

MISCELLANEOUS

Die Casting Dies Require High-Grade Steel and Heat Treatment. J. B. Nealey. *Iron Trade Review*, Sept. 5, 1929, Vol. 85, pages 594–596.

Alemite Die Castings & Mfg. Co. uses Al-base, Zn-base, Sn-base and Pb-base alloys for die castings. Unless the dies used are made of high-grade steel and receive the proper heat treatment to develop the necessary physical properties, the surface will crack and affect quality of product. MS

A Method for the Growth of Single Crystals of Low Melting Point Metals in Vacuum. J. H. Dillon. *Review of Scientific Instruments*, Jan. 1930, Vol. 1, pages 36–38.

Article describes a design of an apparatus used in a method, for "outgassing" crystals, which is a modification of Bridgman's method.

The Immediate Aim of Aeronautical Research. H. E. Wimperis. *Journal Royal Aeronautical Society*, Jan. 1929, Vol. 33, pages 75–82.

Airplane engine failures, when they do occur, are as often as not caused by the breakage under vibration fatigue of some small pipe line such as it is difficult to guard against even by the almost perfect system of inspection now in force.—*From abstracts prepared by the A. T. S. M. Committee on Fatigue of Metals.*

Doublé as a Construction Material. (Doublé al Werkstoff für den Apparatebau.) George Durst. *Chemiker-Zeitung*, Oct. 30, 1929, pages 837–838.

By "Doublé" is meant a combination of metal produced by interwelding; that is, 2 or more layers of different metals are united at high temperatures under pressures of several hundred atmospheres, without the use of solders or the like, so that they cannot be separated again by mechanical means. Further treatment of Doublé by rolling, drawing, pressing, etc., as in the case of a simple homogeneous material of construction, is carried out only after the individual layers are united as a result of the welding. The making of welded seams such as are necessary in many apparatus, tube connections, etc., presented special difficulty in the case of Doublé, but this was accomplished by altering the structure of the Doublé. A material, Efkabimetal, produced by Fr. Kammerer A.-G., of Pforzheim, has between the noble-metal upper layer and the copper sublayer a firmly welded intermediate layer of a metal that has no, or only an exceedingly slight, tendency to form alloys with the 2 outer layers. In the case of silver–copper Doublé such an intermediate layer consists of iron, nickel or a suitable alloy of the metals of the iron group. Such an intermediate, or enclosed, layer can be made also between gold surface layers. This Doublé construction material might be recommended for many branches of the chemical, physico-chemical, electro-chemical and photochemical industries, in the rectification of chemically pure distillates, in the production of organic preparations and sterile solutions, and for all such purposes where, heretofore, only fine silver or other noble metals could be used. XL

New Methods and Apparatus for the Examination of Molding Sands. (Neue Methoden und Apparate für die Formsanduntersuchung auf der 5, Giesserei-Fach-Ausstellung, Düsseldorf.) *Giesserei-Zeitung*, Oct. 15, 1929, pages 594–595.

Description and application of apparatus to determine moisture, permeability of gases, plasticity and strength of molding sands. Description of vibrators built by Ströhlein & Co. G. m. b. H. Düsseldorf, to determine content of alumina and grain size of sands. GN

Proceedings of the IV International Congress for Scientific Management. (Les travaux de IV congres international de l'organisation scientifique de travail.) M. Androuin & Therese Leroy. *Revue de Metallurgie*, Dec. 1929, Vol. 26, pages 662–679.

An account of the activities of the congress for scientific management held in Paris in the summer 1929. JDG

Densitometer Curves of the Green Mercury Line. R. W. Wood. *Philosophical Magazine*, Aug. 1929, Vol. 8, pages 205–207.

By means of a Moll registering photometer, densitometer curves of spectrograms taken with the light of a glass Cooper-Hewitt mercury arc have been made in order to examine the nature of the absorption, by mercury vapor, of the satellites of the green mercury line. One photograph was made with the light emerging from the side of the tube, and another with the tube end-on, the spectrum in the latter case being modified by absorption in the long column of luminous vapor.—*Abstract Bulletin Kodak Research Laboratories.*

FURNACES AND FUELS

New Furnace Enables Producer of Slab Zinc to Improve Product. *American Metal Market*, Feb. 12, 1930, Vol. 37, No. 30, page 5.

The Atlantic Zinc Works, in conjunction with the Ajax Metal Co. have developed an electric induction furnace putting under positive electric control, the operations of melting, mixing and casting zinc. Careful inspection for uniform thickness, flatness, temper and etching qualities is conducted. The furnace consists of a cylindrical container lined with heat-resisting clay, in the bottom of which a V-shaped tube, about 1/2-inch in diameter, is passed around an electromagnetic coil. A 220-volt circuit passing through the electro-magnetic coil, induces in the molten zinc in the V-shaped tube, a very high current of about 16,000 amperes, and due to the resistance of the molten zinc, heat is generated at a constant rate. The constant power input insures a uniform melting rate. The furnace draws a steady load of 62 kw. and it requires 40 minutes to melt each 950-lb. heat. WHB

The Three Phase Current Arc Furnace. (Der Drehstromlichtbogenofen.) S. Schley. *Giesserei-Zeitung*, Oct. 15, 1929, pages 583–587.

The individual parts of equipment of electric steel furnaces are described. Transformers, reactance coils, regulation of electrodes, high tension switch board, and general rules for the arrangement of electric equipment are considered in detail. GN

Tube Annealing Furnace with Mechanical Charger. (Rohrglühofen mit mechanischer Beschickung.) H. Fey. *Stahl und Eisen*, Oct. 31 1929, Vol. 49, pages 1589–1590.

Description of an annealing furnace (length 40 feet) for annealing tube with simple charging devices. Capacity 80 tons per 24 hr. for tubes 25 ft. long, 2–3" diameter, fuel consumption 6–7% of annealed weight. GN

Regenerative Heating Furnace. (Regenerativ-Gleichstromofen.) H. Fey. *Stahl und Eisen*, Dec. 19, 1929, Vol. 49, pages 1835–1836.

In this new type of heating furnace the gas checkers are eliminated. The air checkers, therefore, must be heated up to about 1200° C., which can only be accomplished by heating with raw gas. The furnace is in most successful application in German steel plants. GN

Electric Resistance Furnaces in the Iron Industry. (Elektrische Widerstandsöfen für die Eisenindustrie.) V. Plaschkis. *Stahl und Eisen*, Nov. 21, 1929, Vol. 49, pages 1685–1695.

Includes discussion. Report No. 72 of the Rolling Mill Committee of the Verein deutscher Eisenhüttenleute. The paper describes a greater number of furnace types as applied to different operations in the iron industry. All furnaces discussed are built by Allgemeine Elektrizitäts Gesellschaft and include furnaces for annealing sheets, heating furnaces, car heating furnaces, tool hardening furnaces, bright annealing furnaces, annealing furnaces with circular cross-section, continuous furnaces for drying sand cores or lacquer on castings or sheets, melting and tinning furnaces. Practical results on operation are given, the advantage of electrical furnaces are considered and summarized. GN

Modern Furnaces and Their Application. R. E. Talley. *Heat Treating & Forging*, Sept. 1929, Vol. 15, pages 1205–1207.

The use of modern automatic furnaces for heat treatment in which temperature and control are accurately maintained has resulted in very considerable economies. The rotary hearth type is one of the most efficient forms of continuous conveyor furnaces for miscellaneous production. The pusher type is also used for miscellaneous parts. MS

New Lining for High-Frequency Electric Steel Furnaces. (Neue Auskleidung für Hochfrequenz-Elektrostahlöfen). *Stahl und Eisen*, Oct. 3, 1929, Vol. 49, page 1461.

Note on a new lining for high frequency furnaces, patented by Vacuum Schmetze, G.m.b.H. Lining is sintered from silica granules mixed with boric acid. GN

Dimensions and Efficiency of Electric Arc Furnaces. (Masse und Leistungen von Elektro-Lichtbogenöfen). E. Kothny. *Stahl und Eisen*, Oct. 10, 1929, Vol. 49, pages 1493–1494.

Abbreviated report of a questionnaire sent to 5 German and 13 foreign electric steel plants by the Electric Furnace Committee of the Verein deutscher Giessereifachleute on electric arc furnaces. Originally published in Zeitschrift des Oberschlesischen Berg-und Hüttenmännischen Vereins 1929, pages 300–307. Data on dimensions, electrical equipment, time of melting and refining, power efficiency, lining, consumption of refractory materials and electrodes. The efficiency factor was raised from 50 – 65% in the last 10 years. GN

Semi carbonization and manufacture of metallurgical coke from the mines of the Sarre basin. (Application de la semi-carbonisation et fabrication du coke metallurgique aux mines domaniales de la Sarre). Ch. Berthelot. *Revue de Metallurgie*, Nov. 1929, Vol. 26, pages 571–592.

Sarre basin produces 13 million tons, a quarter of all French coal. Highly developed iron industry is handicapped there by poor coking qualities of the coal. Excessive fragility of the coke made of it prevents the increase of blast furnace size above 250 tons daily production. In coking the density and the loss of weight are functions of the increasing temperature. A plane defined by the isotherms in the mass of coking coal is subjected to tangential strains from both sides destroying its continuity and resulting in friable coke. The introduction of coke or hard coal in the charge changes the direction of fractures lessening thereby their effect on the brittleness of the coke. An addition of about 55% (by weight) coke or 100% of hard coal furnish a good coke, especially when the latter contains about 10–15% volatile matter. Semi carbonization of washing fines of the Sarre coal yields a satisfactory substance for this addition. It might be done in Illingworth or Cantieny ovens producing coke or in powdery form using Salerni apparatus. The selection depends on the economical considerations. Ovens with internal heating are less advantageous under the local conditions that the externally heated. Semi coking not requiring temperatures higher than 550° can be conducted in many types of ovens, though metallic are to be preferred from the financial standpoint. Smokeless fuel with 6–8% volatile matter or semicoke with about 12% V. M. can be made. Heinitz plant producing 150 tons of coke a day is described. Powdery coke is made there in Salerni ovens run at 500° and having a movable bottom. The furnace needs less metallic parts than any other type requiring not more than 300 kgs. per ton hour. Its product is quenched by mixing with moist fines. No ammonia is produced. The tars have almost the density of water, form easily an emulsion with it and for separation a tank heated to 80° is required. Numerous data are given. A brief description of the development of Bergius process is included and a paragraph on the possibilities of tar hydrogenation. JLG

Melting Aluminum in Electric Furnaces. (La fusion de l'aluminium au four electrique.) A. Balin. *Journal du Four Electrique*. Nov. 1929, Vol. 38, pages 377–380; Dec. 1929, page 416.

Furnaces used for melting aluminum are almost always of resistance type and must produce uniform heat throughout to allow casting at 570° without overheating the metal more than 800–850°. The maximum oxidation loss occurs when the metal passes from solid to liquid state. This loss, in properly constructed furnaces, can be reduced to 1–2%. Crucible furnaces of Russ type are described. JDG

Semi-Automatic Forging Furnaces. J. B. Nealey. *Heat Treating & Forging*, Oct. 1929, Vol. 15, pages 1343–1344.

Slot-type, automatic gas furnaces were adopted for heating drill steel and cutter bits used in coal mines. Slow and uniform heating and volume of production were obtained with this type. The bits are hardened without reheating. MS

Electric Melting Furnaces. (Elektro-Giess- und Schmelzöfen). R. Gross *Siemens Zeitschrift*, Nov. 1929, pages 772–779.

Description of alternating current arc furnaces, low frequency and high frequency induction furnaces. GN

Selecting Heat for Heat Treating. Robert M. Keeney. *Iron Age*, Jan. 9, 1930, pages 148–150.

Abstract of an address before the New York chapter of the American Society for Steel Treating, Dec. 9, 1929. Heat for industrial heat treatment of metals should be decided by the economics of the situation, as shown by the overall cost of the product for the different forms of heat. Items influencing overall cost are: fuel, power, labor, maintenance, etc. The tendency of using one source of heat for many different heat treating operations is disappearing. Heat best suited for one operation may not fit another. Discusses factors favoring the use of electricity, gas, oil or wood. Considers the cost problems in steel and non-ferrous heat treatment. VSP

A Pulverized Fuel Furnace for Melting Cast and Malleable Cast Iron. J. E. Fletcher & J. G. Pearce. *British Cast Iron Research Association, Research Report* No. 80.

An account of the melting procedure, capital and working costs of the recently developed Brackelsberg Furnace.

Coke Tests in Cupola Practice. J. E. Fletcher. *British Cast Iron Association, Research Report* No. 78.

The results of practical full scale cupola tests on bee-hive and patent cupola cokes. The tests show the improved melting efficiency with correctly graded coke of suitable properties.

REFRACTORIES AND FURNACE MATERIALS

Refractory Materials Should Be Selected to Meet Each Need. *Grits & Grinds*, Dec. 1929, Vol. 22, 12 pages.

Norton refractories are made from 3 raw materials: electrically fused alumina, silicon carbide and electrically fused magnesia. These are used in various forms, such as, grains, cements, bricks, plates and blocks. The use of these different forms in furnaces, kilns, fireboxes, etc., is described. Crucibles for melting ferrous and non-ferrous metals are made from the 3 materials. MLM

Refractory Materials for Foundries. (Feuerfeste Materialien für Giessereizwecke). W. M. Cohn. *Giesserei-Zeitung*, Oct 15, 1929, pages 588–593; Nov. 1, 1929, pages 614–619. *Metallwirtschaft*, Nov. 29, 1929, pages 1163–1168; Dec. 6, 1929, pages 1191–1194.

The main viewpoints, which are to be considered in selecting the best suited refractory materials for furnaces are summarized. Chemical and physical properties, test methods and apparatus are described. Expecially emphasizing the behavior in heating and cooling, specific heat, heat expansion, heat conductivity, softening under pressure, stability towards changing temperatures and extreme high temperatures, stability towards attack of slags, dust and gases are dealth with. Finally the application of refractories for cupolas is discussed. GN

INSPECTION

Askania Tube Camera. (Askania Rohrkamera). *Stahl und Eisen*, Dec. 19, 1929, Vol. 49, pages 1838–1839.

The Askania-Werke, Berlin-Friedenau, have built an instrument with which roll film pictures can be taken of the inside walls of hollow bodies. The camera can be applied to investigate failures of material, as cracks, defective machining, wearing of hollow bodies and for many other purposes. GN

Polished Chromium Plating Is Carefully Inspected. E. W. Beggs. *Electric Journal*, Feb. 1930, Vol. 27, pages 112–113.

A newly developed inspection booth, of laboratory model, has high-intensity lamps concealed in the upper fore part of the apparatus, and the articles to be examined are placed on the surface of the table. A conveyor belt permits rapid and easy inspection of the plated parts as they pass by the right half of the apparatus, the observation of any thinness or voids in the plating as slightly discolored or darkened spots, also scratches or pits. The black lines, covering only the left half of the background, serve to disclose irregularities in the surface of the metal. The scheme may be applied to nickel, silver, steel and other highly reflecting surfaces. The booth and the appearance of irregularities, poor polish, voids, etc., are illustrated, and a table shown of defects of chromium plating and their means of detection. WHB

GASES IN METALS

Influence of Nitrogen on Special Steel. Shun-Ichi Satch. *Heat Treating & Forging*, Dec. 1929, Vol. 15, pages 1583–1588.

Bibliography of 75 references. Paper before American Institute of Mining & Metallurgical Engineers. Translated from Japanese journal, *Tetsu, to Hagane*, Aug. 1928. Translated also in *Revue de Metallurgie*, May 1929, for abstract of which see Metals & Alloys, Sept. 1929, Vol. 1, pages 118–119. MS

Influence of Atmospheres on the Heat Treatment of Steel. R. G. Guthrie. *Fuels & Furnaces*, Sept. 1929, Vol. 7, pages 1345–13544.

Five different types of steel were carburized at 1800° F. for 5 hrs. with varying amounts of the same gas at the same velocity and pressure. Varying case depths and carbon concentrations were obtained. Decarburization experiments with a eutectoid steel heated at 1500° F. for 2 hrs: in dry O_2, dry CO_2, superheated steam, dry H_2, and stagnant air, indicated that CO_2 is the most rapid decarburizer of these gases. Steels heated at 1500° F. for 5 hrs. in varying proportions of CO and CO_2 showed considerable decarburization when the CO_2 was greatly in excess. With different mixtures of CO and H_2 there was no appreciable decarburization. Surface conditions of the steels showed that decarburization may exist with or without external scaling. Changing the rate of flow of a given gas over the work will give any desired result from decarburization through many degrees of carburization. By varying the moisture content of a gas, its efficiency as a carburizing medium may be varied quite widely. Includes numerous photomicrographs. MS

The Unknown Influence of Oxygen and Nitrogen on Iron–Carbon System. H. W. Gillett. Metals & Alloys, Nov. 1929, Vol. 1, pages 237–239.

A correlated abstract summarizing the results of recent investigations.

The Occlusion of Hydrogen and Nitrogen by Pure Iron and Several of Its Alloying Elements. (Ein Beitrag zur Frage der Aufnahmefähigkeit des Reinen Eisens und einiger seiner Leigierungselemente für Wasserstoff und Stickstoff). E. Martin. *Archiv für Eisenhüttenwessen*, Dec. 1929, Vol. 3, pages 407–416; *Stahl und Eisen*, Dec. 26, 1929, Vol. 49, pages 1861–1863.

The solubility of nitrogen and hydrogen was determined by measuring the volume of these gases in the atmosphere surrounding the sample at different temperatures and comparing it with the volume of argon, which does not dissolve in metals. In electrolytic iron with 0.02% impurities and 0.007% C. the A_3 point is indicated very slightly by the solubility of H_2. The solubility for N_2 at this point shows a marked increase and gradually decreases with increasing temperature in the γ-phase. The agreement with the results of Sieverts and Jurisch (*Zeitschrift für Metallkunde*, Feb. 1929, Vol. 21, page 37–46) is perfect. The curves of Keizô Iwasé could not be checked (Science Reports, Tohoku University, 1926, Vol. 15, No. 4, pages 531–566). The solubility of N_2 in the γ-phase is about 16 cm^3 in 100 gm., the solubility in α-iron is very low. The solubility of H_2 in chromium is lower than in iron. With N_2, chromium forms a nitride above 600° C. which is very stable. It could not be decomposed even at a temperature of 1200° C. and a vacuum of 0.001 mm. The solubility in molybdenum is still lower both for H_2 and N_2. No solubility could be observed in tungsten up to a temperature of 1200° C. The author also investigated the solubility of H_2 and N_2 in Fe-Si alloys. It should be noted that the solubility in these alloys which are outside of the γ-range is small even at temperatures up to 1250° C. The nature of the gases in the metals is discussed. It cannot be stated at the present time, whether the gases are dissolved in the base metal in form of atoms or in form of intermetallic compounds (nitrides and hydrides). It is of interest that the lattice of the γ-iron which is more closely packed with atoms has a higher solubility for gases than the lattice of α-iron. CK

EFFECT OF TEMPERATURE ON METALS AND ALLOYS

The Effect of Various Temperatures on Aluminum Alloys. (Die Wirkung von Verschiedenen Temperaturen auf Aluminiumlegierungen.) E. Bachmetjew. *Metallbörse*, May 11, 1929, pages 1043–1045.

A study was made to determine the tensile strength of the usual aluminum alloys at elevated temperatures. The data from 10 different cast alloys, of pure aluminum and the influence of various heat treatments are given. The important temperature range of 24–427° C. was covered and some tests at still higher temperature carried out. Apparatus, method of investigation and results obtained are discussed. EF

Effect of Small Changes in Temperature on the Properties of Bodies. Mayo D. Hersey. *Bureau of Standards, Journal of Research*, Jan. 1930, Vol. 4, pages 137–156.

When it is found necessary to determine the effect of small departures from normal temperature upon some property of a body or system of bodies, such as the stiffness of a steel spring, the vibration frequency of a tuning fork, or the accuracy of an instrument, it is usually done either (a) by a detailed computation or (b) by a direct experiment in which the temperature is actually varied. After reviewing and illustrating the usual methods of solution a general mathematical treatment of the problem is given, from which two additional methods are derived that can sometimes be usefully applied: (a) a simple calculation, made possible by the theory of dimensions, which does not require any detailed formula for the property in question; and (b) a combined theoretical and experimental solution, in which the experimental factors have been reduced to a minimum and can be determined without varying the temperature of the body itself, provided the thermal properties of the component materials are known. Finally it is pointed out that the same treatment can be extended to any other condition analogous to temperature, such as hydrostatic pressure. XL

Selecting Metals for High-Temperature-Pressure Requirements. S. D. Kirkpatrick. *Chemical & Metallurgical Engineering*, Sept. 1929, pages 526–527.

Outlines investigations on "creep" carried out by the Standard Oil Development Co. at Linden, N. J. For their purpose, the limiting creep stress is defined as that stress which will produce 1% elongation in 100,000 hours, 50,000 hours or 25,000 hours, depending upon equipment to be built. MS

The Thermal and Elastic Properties of Elinvar: A Study of an Elinvar Spring in the Galitzin Vertical Seismograph at Kew Observatory. F. J. Scrase. *Journal of Scientific Instruments*, Dec. 1929, pages 385–392.

A serious defect of the Galitzin vertical seismograph is the drift of the pendulum which is caused by the effect of temperature changes on the elasticity coefficient of the steel spiral spring. In order to overcome this disadvantage an elinvar spring was recently fitted to the vertical seismograph at Kew Observatory. After loading the spring the "creep" remained appreciable for several months. Moreover the rate of "creep" was dependent on the temperature. After making due allowance for these effects it was found that the temperature coefficient of the elastic constant of the elinvar spring was $^1/_{10}$ that of the steel spring. MBR

EFFECTS OF ELEMENTS ON METALS AND ALLOYS

The Effect of Lead on the $\alpha + \beta/\beta$ Equilibrium in a 60/40 Brass. L. R. van Wert. Metals & Alloys, Nov. 1929, Vol. 1, pages 200–205.

This paper discusses the experimental results of an investigation to determine the qualitative effects small amounts of lead have on 60/40 brass. Discussion Dec. 1929, page 262.

Nickel and Chromium Extend the field of Application of Iron Castings. F. B. Coyle. Metals & Alloys, Dec. 1929, Vol. 1, pages 272–275.

The author indicates in a brief survey how the alloying elements nickel and chromium can be used not only as foundry tools but to extend the use of common gray iron into special and broader fields.

Effect of Small Quantities of Third Elements on the Aging of Lead-Antimony Alloys. Earle E. Schumacher, G. M. Bouton & Lawrence Ferguson. *Industrial & Engineering Chemistry*, Nov. 1929, pages 1042-1044.

The data presented in this article definitely show that small quantities of certain elements when added to lead 1% antimony alloys have a very marked effect on the rate at which antimony is precipitated from supersaturated solid solution. The presence of arsenic seems to increase the rate of precipitation most. Manganese, copper and silver are not quite as effective. The precipitation after the first three days is retarded by nickel. Concentrations of third element from 0 to 0.01% are most effective. MEH

Effect of Alloying on the Permissible Fiber Stress in Corrugated Zinc Roofing. E. A. Anderson. *Technical Publication* No. 232, *American Institute of Mining & Metallurgical Engineers*, 9 pages.

Developments and testing of a zinc alloy corrugated sheet having a sufficiently high safe working stress to permit its use on purlin spacings in the same range as those used for steel sheets are outlined. Some general considerations concerning the metallography of the Cu-Mg alloy developed are discussed. The author refers to his previous publications on determination of safe maximum fiber stresses in corrugated zinc roofing sheets. EF

Low-Cost Corrosion Resistance with Alloyed Cast Iron. J. S. Vanick *Chemical & Metallurgical Engineering*, Sept. 1929, pages 537–539.

Si, Ni, Cr, Cu and Mn are usually alloyed with gray iron to improve corrosion resistance. Si decreases corrosion in tap water and sea water, and increases it in soil, acid and alkaline solutions. Ni reduces corrosion in tap water, soil, sea water, acid and alkaline solutions. Cu is effective against acid solutions, sea water and atmospheric attack, but is detrimental in tap water, distilled water and alkalis. Cr in small additions is effective against tap water, sea water and acids. In addition to effect on corrosion resistance, the effect of the alloying elements on such properties as castability, machinability, and strength must be taken into consideration. Ni and Cr and to a lesser extent, Mo, are added to cast-iron to improve resistance to wear. Ni, or Ni and Cr, are the principal elements used to improve pressure castings. Ni, with Si and Mn, are used in the production of high-strength cast-iron. MS

Platinum Contamination of Palladium in Palladium Point Determinations. C. L. Utterback. *Review of Scientific Instruments*, Jan. 1930, Vol. 1, pages 39–44.

Palladium in contact with platinum, has been heated to the melting point starting with different initial temperatures. Different methods of contact and different times of heating were used. Spectrographic, photomicrographic and chemical analyses show definite contamination which increases with both temperature and time. Palladium point determinations indicate that this contamination may account for inconsistent results observed in the melting point.

The Influence of Silicon on the System Iron–Carbon–Phosphorus. (Der Einfluss des Siliziums auf das System Eisen-Kohlenstoff-Phosphor.) O. von Keil & R. Mitsche. *Archiv für das Eisenhüttenwesen*, Aug. 1929, Vol. 3, pages 149–156; *Stahl und Eisen*, Oct. 3, 1929, Vol. 49, pages 1454-1455.

Tests with alloys containing from 1.2–6% Si show different structures depending upon the eutectic or non-eutectic composition of the melts. Hypoeutectic melts contain graphite finely divided, whereas hyper-eutectic melts have graphite in flakes. The difference in the segregation of graphite depends upon the kind of solidification, whether metastable or stable. Influence of cooling rate and alloying elements was investigated. Furthermore the transition of the line C E in the ternary system Fe–C–P was studied with alloys of 1.2, 1.8 and 2.8% Si. Phosphorus favors the metastable phase, i.e. the segregation of fine graphite. Etching was performed by a simplified method with neutral sodium picrate. GN

The Influence of Phosphorus, Silicon and Nickel on the Solubility of Carbon in Liquid Iron. (Ueber den Einfluss der Liegerungselemente Phosphor, Silizium und Nickel auf die Löslichkeit des Kohlenstoffs im flüssigen Eisen.) K. Schichtel & E. Piwowarsky. *Archiv für das Eisenhüttenwesen*. Aug. 1929, Vol. 3, pages 139–147; *Stahl und Eisen*, Sept. 12, 1929, Vol. 49, pages 1341–1342.

The influence of the mentioned elements on the capacity of liquid iron to dissolve graphite was investigated. The melting curve C′D′ in the iron-carbon system was re-established and confirmed as given by Ruer and Ziren (Zeitschrift für anorganische Chemie, 1920, Vol. 113, pages 98–112). In the iron-silicon alloys the saturation lines are approximately parallel to C′D′ in the iron-carbon system. The effect of silicon to supplant carbon is not the same for all contents of silicon. Smaller amounts up to 2% silicon have a greater effect than larger amounts. The tendency of silicon to supplant carbon increases with the temeprature, above 3% Si: at 1200° C., 0.28% C. per percent Si; at 1700° C., 0.46% C. per percent Si. The effects of phosphorus are similar. In comparison to silicon and phosphorus, nickel shows some remarkable differences. The influence of nickel is much less. The eutectic temperature (metastable system) of about 1150° C. at 0% Ni increases to 1240° at 32% Ni, but the eutectic concentration of carbon decreases for the same content of nickel from 4.25–3.1%. Up to 15% nickel the decrease of carbon is independent of the nickel content, but above this concentration 1% of nickel supplants 0.045% carbon at all temperatures. Tests were made with samples containing both silicon and nickel. GN

Investigations on the Influence of Accompanying Elements, especially Oxygen, on the Segregation of Steel. (Untersuchungen über das Verhalten der Begleitelemente des Eisens, insbesondere des Sauerstoffs bei der Leigerung des Stahles, mit Beiträgen zur Sauerstoffbestimmung.) P. Bardenheuer & C. A. Mueller. *Mitteilungen Kaiser Wilhelm Institut für Eisenforschung*, 1929, No. 16, Report 133, Vol. 11, pages 255–272; *Stahl und Eisen*, Dec. 12, 1929, Vol. 49, pages 1804–1805.

Steel was melted in a 50 kg. high frequency furnace, cast in small ingots (350 mm. high, 140 mm. diameter) and tested, chemically and microscopically. Eight samples, tested, contained no silicon, less than 0.10% C and variable amounts of phosphorus, sulphur, copper and oxygen. S and P have the greatest tendency to segregation, Cu and Mn only to a small degree. Oxygen segregates more than Cu or Mn. P and S segregate at the same place, probably similar relations exist between segregations of Cu, Mn and S. Increasing segregations of P and S result in decreasing segregation of oxygen. The hydrogen-reduction method for determination of oxygen is influenced by the amount of P. Two examined ingots higher in carbon, no silicon, show least segregation in the center of the lower part. In this case oxygen segregations could be located at the same places as the other elements. Segregation of silicon steels is lower. Degree of segregation of all examined elements is increased with increasing content of oxygen. GN

INSTRUMENTS AND CONTROLLERS

Instrument to Measure Contraction. (Vorschlag für ein Messgerät zur Betimmung der Kontraktion.) F. Hönig von Honigsberg. *Stahl und Eisen*, Dec. 12, 1929, Vol. 49, pages 1800–1801.

The instrument, sold by Mohr & Federhaff, permits the simple accurate determination of diameter changes of test samples while being stretched or compressed. GN

Temperature Control in the Heat Treating Shops. (Temperaturüberwachung im Härtereibtrieb.) W. Jaeckel. *Siemens Zeitschrift*, Nov. 1929, pages 807–813.

Temperature control instruments, as thermoelectric, radiation and pyrometers, as well as recording instruments are described and illustrated. GN

Realization of the Black Body at the Melting Point of Palladium, by the Tube Method. G. Ribaud & S. Nikitine. *Annales de Physique*, July-Aug. 1929, pages 451–482.

The author describes a new pyrometer and discusses some of the phenomena connected with the fusion of palladium. *Abstract Bulletin Kodak Research Laboratories.*

A New Pocket Pyrometer. (Ein neues Taschenpyrometer.) *Giesserei-Zeitung*, Nov. 1, 1929, page 610.

The pyrometer, invented by G. Näser, Kaiser Wilhelm Institut für Eisenforschung and made by Ströhlein & Co., Düsseldorf, uses a precision color glass with increasing color density. In sighting a hot specimen the change of color of a light filter from red to green is indicated by a mixed color, nearly white, which gives the temperature of the specimen. The instrument offers many advantages in comparison to the known pyrometers. GN

Translation

Negotiations are under way which will assure the appearance of translations of articles appearing in foreign publications. Under this arrangement, the readers of METALS & ALLOYS *will be assured of receiving in English the best articles shortly after they appear abroad.*

The Application of Spectrographic Analysis in Iron and Steel Laboratories

By K. Kellerman, Ph.D. Clausthal, Germany

(Translated by Special Permission from Bericht No. 66 of the Chemikerausschuss of the des Vereins deutscher Eisenhüttenleute and published in Archiv für das Eisenhüttenwesen, September 1929, pages 205–211.)

The better production, in which chemical processes are important, may be controlled by quick and accurate analysis, the more certain and efficient it is. The necessity for rapid analytical methods increases with the striving for production efficiency. This is especially true with alloys in which amounts of additions though very low (0.01%) still have a considerable influence on the structure and quality. It proves the need for qualitative and quantitative analytical methods for such constituents present in the alloy, intentionally or by chance. Gravimetric analysis can hardly be improved so as to be suitable for quick analytical purposes and for very small amounts. Physico-chemical methods must fill the gap. Electrometric titration in which no precipitate is formed has been applied to a certain extent. Colorimetric analysis is also used to advantage. For certain elements distinct reactions and microchemical methods have been found. Yet none of these methods can be used in all cases, especially as most of them depend too much on the amount of other constituents present.

The spectrographic analysis gives promise of being useful in all cases. It has already been used considerably for qualitative analysis on account of its high sensitivity especially for the determination of alkalis. The question of to-day is the possibility of its application for quantitative analytical purposes. In the handbook by Kayser, the basic work on spectroscopy, it is stated (1910) that a quantitative spectrographic analysis had proved to be impossible. Yet it seems as if different investigations had changed this situation. To-day we already have analytical methods in view which may be successfully applied to production requirements.

The high sensitivity of the spectrographic method, very valuable for qualitative analysis, acts as an impediment for its use for quantitative analysis. Constituents present in only very small amounts are determined spectroscopically, the concentrations seem to be of no influence. Hartley (1884) stated the following fundamental fact: if the concentration of a constituent in an alloy decreases, less lines of the constituent appear. Taking small amounts of about 1%, only a number of lines remain, which can be easily traced. If the concentration decreases still further, the number of lines also decreases until all of them disappear. The lowest concentration showing at least one line is very low, in the neighborhood of 0.001 to 0.0001%.

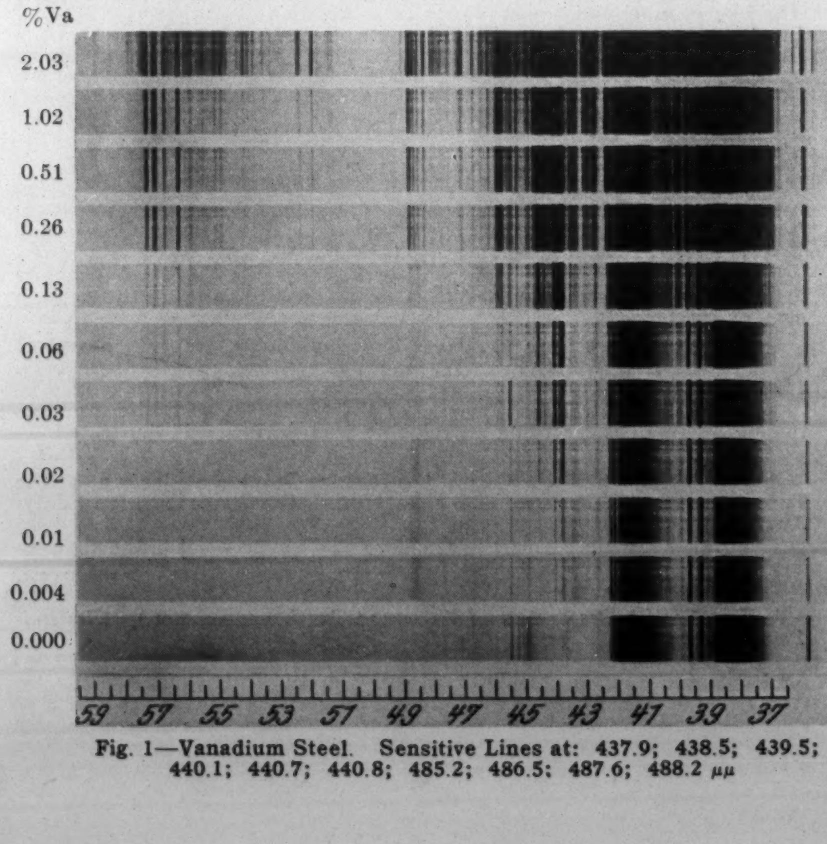


Fig. 1—Vanadium Steel. Sensitive Lines at: 437.9; 438.5; 439.5; 440.1; 440.7; 440.8; 485.2; 486.5; 487.6; 488.2 $\mu\mu$

A spectrum obtained by using a solution of a vanadium steel (Fig. 1) explains this statement. The first spectrum (2% Va) shows a considerable number of lines. It decreases with the concentration. The intensity also decreases with the concentration, line 440.9 $\mu\mu$ occurs to 0.004% Va, line 485.2 $\mu\mu$ only to 0.02% Va, under the given conditions. The concentrations are graduated so that each following solution has only half of the concentration of the preceding. If the line 440.8 is not found in a certain sample, it is certain that, if vanadium is present at all, it can range only below 0.004%. With higher concentrations the difference between the intensities is less pronounced. It is, therefore, necessary to use lines which already diminish at these concentrations. Finally, a concentration is reached where the mere chemical analysis, though it requires a longer time, is more useful.

The vanishing of the lines—as Gerlach[1] states—is only a question of energy. The originally strongest lines vanish last. In most cases photography is successfully used for registration. If the intensity of the line is below a certain minimum value of the sensitivity of the plate it is not registered. By a longer exposure by applying higher energy for the arc the lowest intensity shown by the plate may be decreased still more. As the relative difference of intensity decreases with increasing concentration the upper limit of application is given. It may sometimes vary, but is practically about 1%.

The examination of those "last lines" enables one to use the spectrographic analysis for quantitative purposes. This fundamental principle has been developed by several investigators, especially de Gramont. It is not necessary to deal with the history because of the complete survey given by Loewe.[2] The fundamental principles of the method may be briefly discussed as they may give an idea as to how far these methods can be used in iron and steel plants.

The quantitative determination comprises 3 parts: the samples are caused to emit light; a spectrogram of this light is taken and registered by a photographic plate; the spectrograms are measured and interpreted.

Experience has shown that only the electric arc can be used for the initiation of light. It can easily be duplicated. Alternating current (about $^1/_2$ kw.) is used and transformed to about 10,000 volts. Parallel to the arc a condenser is used (2–10,000 cm.) to condense the discharge. The current passes an induction coil, the size of which is best determined by experiment. The coil must be approximately 5 cm. in diameter and have 80 to 100 windings. Figs. 2a and 2b give the arrangement of the condenser, the induction coil and the arc for the use of alternating and direct current, respectively. By increasing the induction the number of lines decreases if no other conditions change. At first the "air lines" resulting from the stimulation

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[1] *Zeitschrift für anorganische Chemie,* **142,** 385 (1925).

[2] *Optische Messungen des Chemikers und Mediziners* (Leipzig, 1925).

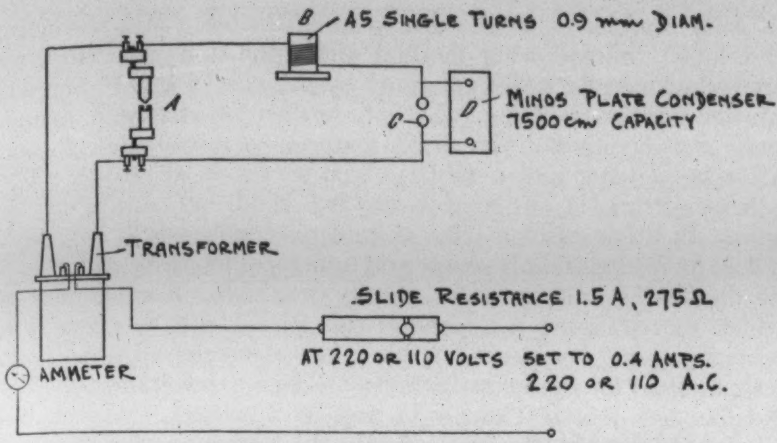
B
A5 SINGLE TURNS 0.9 mm DIAM.
A
C
D
MINOS PLATE CONDENSER
7500 cm CAPACITY
TRANSFORMER
SLIDE RESISTANCE 1.5 A, 275 Ω
AT 220 OR 110 VOLTS SET TO 0.4 AMPS.
220 OR 110 A.C.
AMMETER

Fig. 2a—Alternating Current Circuit for Emission Spectra

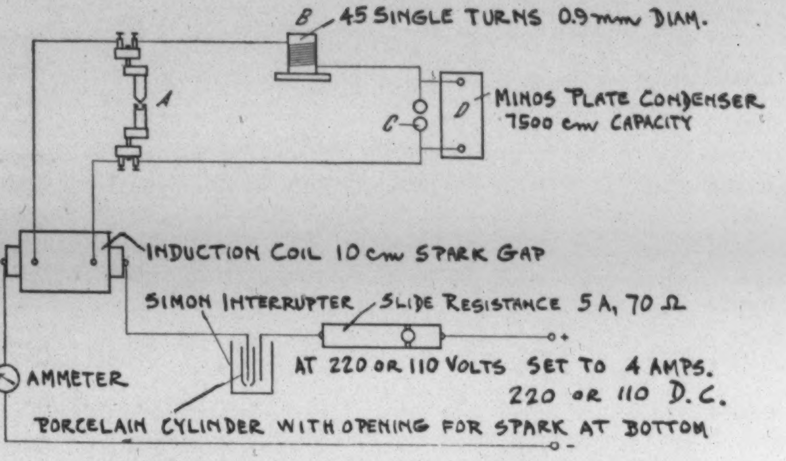
B
45 SINGLE TURNS 0.9 mm DIAM.
A
C
D
MINOS PLATE CONDENSER
7500 cm CAPACITY
INDUCTION COIL 10 cm SPARK GAP
SIMON INTERRUPTER
SLIDE RESISTANCE 5 A, 70 Ω
+
AT 220 OR 110 VOLTS SET TO 4 AMPS.
220 OR 110 D.C.
AMMETER
PORCELAIN CYLINDER WITH OPENING FOR SPARK AT BOTTOM
-

Fig. 2b—Direct Current Circuit for Emission Spectra

of the air molecules are suppressed. Using higher induction the weaker lines of the metal vanish also. Enough induction should be used so that with the given conditions the number of lines may be traced. The easiest way is to strike the arc between 2 electrodes of the alloy to be examined. Yet it is possible to use solutions as electrodes; the difficulties originating from this method, though, are greater.

The optical arrangement causes no difficulties and works with high accuracy and reliability. The apparatus is illustrated in Fig. 3. The metal samples are put into the de Gramont arc stand. The arc between the electrodes is reproduced on the slit of the spectroscope. The light is divided in the spectroscope and the lines are registered by a plate. The whole apparatus must be well centered. It is necessary to always have the same photographical conditions to produce the same values (same plate, exposure, time of developing, developer concentration and temperature). For the short wave ultra-violet part of the spectrum the plate must be sensitized; according to a process developed by the Zeiss Works, it is best to use vaseline oil. Petroleum or lubricating oil may also be used. The fluorescence of these oils imposed on the plate in a very thin film is utilized. Before developing, this film of oil must be removed by means of alcohol.

According to de Gramont the spectrum is interpreted by comparing it with different spectra obtained with certain known concentrations. In this way a concentration interval into which the sample belongs is determined by the comparison. At first investigators were content to have values in steps of $^1/_{10}$%. Using special precautions, we[3] were successful in drawing the limit much closer.

It is necessary to have entirely equal conditions of the arc in order to be able to compare the spectra. Yet the arc oscillates between the electrodes and changes in the resistance of the arc result from that fact. The effect is naturally seen on the photographic plate. The best method to avoid these difficulties is given by Gerlach and Schweitzer.[4] The principle is to pick out the so-called "homogeneous line pairs" of the spectrum, i. e., one line of the constituent and one of the base substance which have the same intensity at the given concentration. For different concentrations different homogeneous lines may be found, so that the concentration can be obtained by comparison. It is desirable to have these lines as close together as possible, if this is not the case a line of a third substance may be superimposed on the spectrum and the lines of the constituent brought into correlation with these new lines. As these spectra are formed by the same arc it is no longer necessary to take the change of the electrical conditions into consideration. The method has as yet been tested only for solid electrodes but it is being improved by the authors, so that one may hope to shortly be able to also use it for liquid samples.

By an investigation carried out by Scheibe and Neuhäusser[5] another improvement was obtained. The authors placed a logarithmic sector in the path of the rays, so that the homogeneous lines are measured by means of photometry. Equal intensities give equal length of the homogeneous lines in that case. The method is, therefore, more accurate and convenient.

Another very important improvement results from the method of Schweitzer and Gerlach.[6] A fracture of a lead-gold-alloy was used as electrode and gave at the beginning more lines of lead than a polished surface. This indicates that most of the lead is present at the fracture, i. e., at the crystal boundaries. This result could never have been obtained by metallographic methods. This method gives something like a "topography" of the structure, which may have considerable importance for the examination of ores, etc.

Using solid electrodes, only the surface of the sample is examined. If the material is not homogeneous throughout, difficulty arises therefrom. This may only be overcome by the use of samples in solution. Hartley worked with solutions but his method cannot be applied for practical purposes. That of the Zeiss Works is supposed to be used most generally. Two carbon electrodes are used. The lower has a cavity put into it to hold the solution, a drop of which is sufficient to carry on the investigation. The possibilities of this method can be seen from the investigations by Loewe[7] who gives the spectra of almost all elements. The last lines have in all cases been obtained by using carbon electrodes. The concentrations are graduated in steps of $^1/_{10}$%. In many cases the results could have been given with greater accuracy. Yet the use of carbon brings about

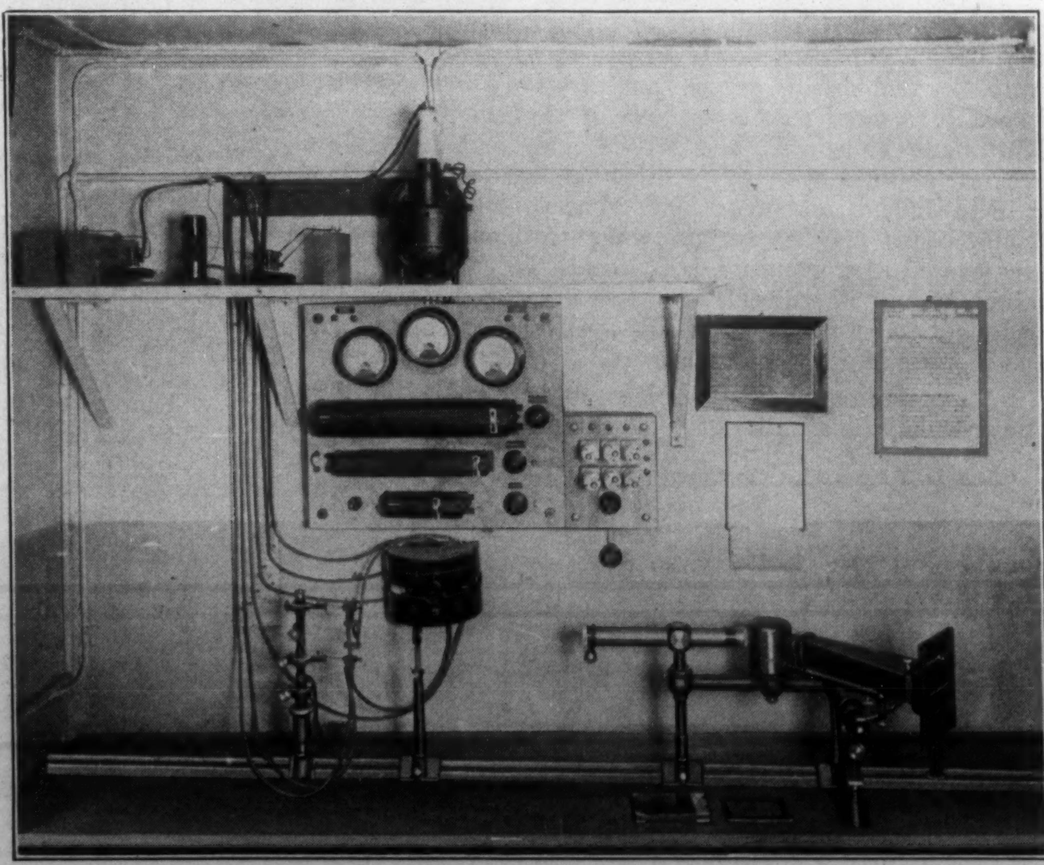

Fig. 3—Apparatus for Emission Spectra Analysis

On the optical bench: arc stand, collecting lens and spectrograph. Above the arc stand on the shelf the transformer, the minos plate condenser and on the bare cylinder is wound the induction spool. Below the transformer: a switch board with slide resistances and measuring instruments.

[3] Kellerman and Schliessmann, *Metallbörse*, **17,** 1068 and 1125 (1927).

[4] *Zeitschrift für anorganische Chemie*, **142,** 383 (1924).

[5] *Zeitschrift für angewandte Chemie*, **41,** 1218 (1928).

[5] *Zeitschrift für anorganische Chemie*, **173,** 104 (1928).

[7] *Atlas der Letzen Linien* (Dresden und Leipzig, 1928).

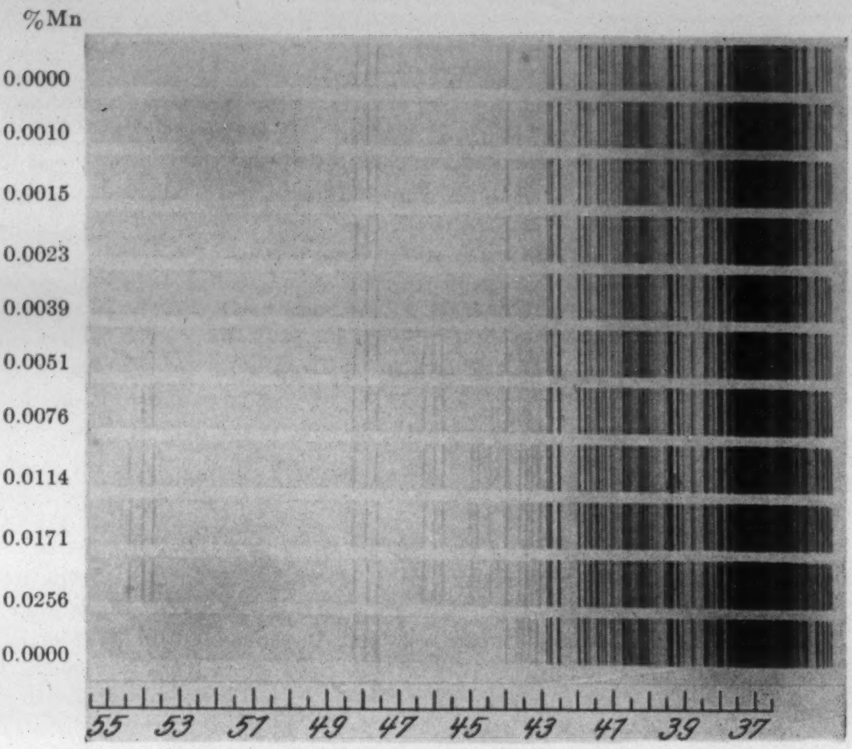

Fig. 4—Molybdenum with Large Amount of Iron. Sensitive Lines at: 416, 438, 441, 444 $\mu\mu$

a disadvantage which can hardly be avoided. It adsorbs the solution to an uncontrollable degree. The first result is, that the burning of the carbon particles resulting from the ignition cause salt vapors which may easily form dispersion spectra. Therefore, the concentration changes quite irregularly. Depending on the other elements present, different amounts of the constituent in question are adsorbed and, therefore, different amounts get into the arc. A large part of the solution is sprayed by the arc and the electrodes become dry during the exposure of the plate. The conditions can hardly be controlled.

A successful method for liquid samples is being worked out by Hüttig and Thurnwald.[8] To the solution to be tested so much of another salt solution is added until two lines become equal in intensity. It is best to take two of the "last lines." From calibrations of different combinations the results may be interpreted. The method is almost similar to that of Gerlach and Schweitzer. It does not depend on the oscillations of the arc and the ranges of concentrations and the limits between which a sample is included may become smaller and more accurate.

The advantages and disadvantages of the different methods are carefully cited by all authors. The de Gramont method of the direct comparison of the intensities is characterized by its simplicity and speed; yet the concentration limits are relatively large. The more recent methods of Gerlach and Schweitzer, Hüttig and Thurnwald, and Scheibe and Neuhäusser are more accurate and reliable. On the other hand, the work of calibration is more difficult and wearisome. The equality in intensity of homogeneous lines at certain concentrations depends on the presence of other elements, i. e., it must be calibrated for each combination. Thurnwald[8] emphasizes that to-day every task for the quantitative spectrographic analysis is just an individual case and requires individual treatment.

In our more recent investigations we were guided by the idea of combining the equality of liquid samples with the advantages of solid samples as to the formation of the arc. We, therefore, developed the following method and applied it especially for iron alloys: a mixture of very pure graphite and a known amount of the solution is dried. Carbon powder or electrode carbon may also be used. The dried material is mixed and pressed after pulverizing into a tablet which serves as electrode. The other electrode in our special case is a small bar of electrolytic iron. In other cases a wire of gold may successfully be used. The arc is remarkably even and quiet. The tests can easily be duplicated and the same results obtained. Further details which would exceed the scope of this survey will be given in a special paper. By means of this tablet electrode all 4 methods may be used for the investigation: Gerlach-Schweitzer, Scheibe-Neuhäusser, Hüttig-Thurnwald and de Gramont. At the beginning, the last method is probably the easiest one for the steel mill chemist; because of the uniformity of the arc by means of the tablet electrode it is no longer so important to use one of the methods that does not depend on the uniformity of the arc and its initiation. Yet with regard to accuracy the absolute methods should be preferred.

Unfortunately iron as base material introduces a considerable number of lines to the spectrum which cover the lines of the constituent in question. It is, therefore, advisable to examine the visible part of the spectrum. The number of iron lines is smaller there and the lines resulting from the constituent may be observed more easily. The cost of the apparatus will be reduced considerably if no quartz is needed. All lenses and prisms can be made of glass.

According to the mentioned considerations the working procedure is as follows:

First the photograms for the comparison must be made. Let us assume that we want to examine molybdenum steel. It would then be advisable to melt steel with graduated amounts of Mo, using electrolytic or carbonyl-iron and pure molybdenum or ferro-molybdenum. Small bars of 30 mm. length and 2 mm. diameter are made and put into the arc stand. The stand can be moved so that the electrodes are placed just opposite one another. The space between the electrodes is always set by means of a glass plate to about 1.5 mm. The arc is at a distance of 1 cm. from the slit. The condenser of 20 cm. focal distance is 25 cm. from the arc. An enlarged reproduction of the arc appears on the diaphragm of the spectrograph. It is advisable to have no sharp reproduction in order to make it independent of the wandering of the arc. The spectrum appears on the focussing screen. By a fluorescent glass fixed to the focussing screen the spectrum can be traced to the ultra-violet. All lines must be of equal intensity for their full length. If that is not the case the apparatus is not well focussed.

If the material to be tested is not homogeneous, also in the investigation of ores, the sample must be fused with flux and dissolved. The calibration is less difficult and more reliable in that case. The sample is dissolved by using adequate chemical reagents. The different concentrations are made by dilution, so that the subsequent concentration is always $^2/_3$ of the preceding (Fig. 4). Using our method of tablet electrodes the solutions are dried with graphite or carbon powder. The pulverized material is pressed to tablets. It is suitable to add 10 or 100 times of an iron solution in excess. Thereby, all influences caused by the presence of iron may be taken into account and may be more or less equalized. As a matter of fact a tablet electrode with a solution of pure iron is also made. By comparing the spectrum of pure iron with one of the material to be examined it

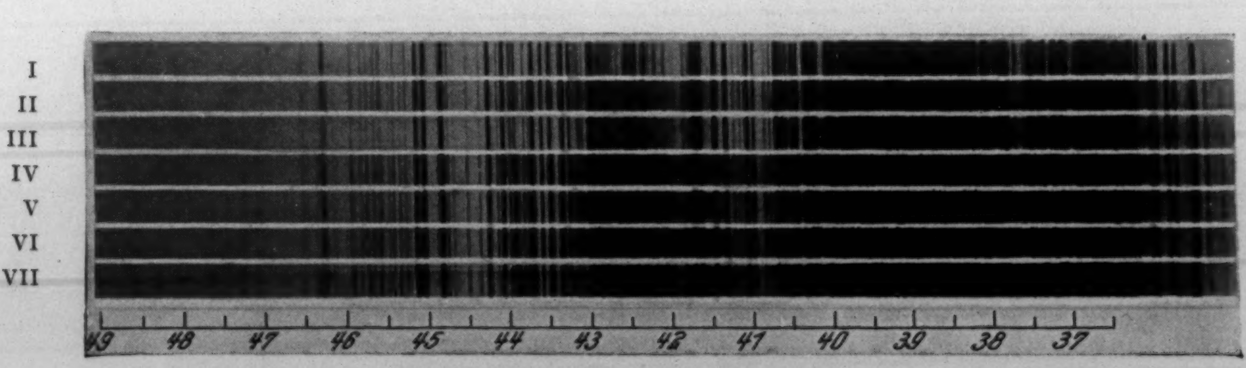

Fig. 5—Spectrogram with Stepped Diaphragm

I, Pure iron; III, V and VIII increasing concentrations; II, IV and VI the required concentration. To the left of mark 44 a pronounced line passes through all spectra; $^1/_2$ mm. to the left of this the sensitive molybdenum line, which appears different in all spectra. Comparison line III is too weak, V about equal, VII too strong; the required concentration is in the neighborhood of comparison concentration V.

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[8] *Zeitschrift für analytische Chemie*, **767**, 263–335 (1929).

may readily be seen if there is any traceable amount of other constituents present or not (Fig. 4).

The plate is exposed 30 to 60 seconds to the arc between the metal and the tablet electrode, using a slit of 0.01–0.03 mm. To make a good comparison possible the different spectra must be located exactly one below another. The plate holder of a spectroscope can usually be moved in vertical direction by mechanical means. It would, therefore, be possible to take the pictures by this device. Yet it is very difficult to move the plate holder exactly parallel to the slit. That may result in a horizontal displacement of the corresponding lines in two following spectra. Besides a great many of plates must be used because each spectrum becomes relatively large. Therefore, it is advisable to use a graduated diaphragm. Only very short parts of the slit are cut out by this diaphragm. A shifting in horizontal direction brings distinctly separated parts of the slit into action. The accuracy in the position of the lines in different spectra is assured and a good comparison possible. The graduated diaphragm divides the slit into 7 parts. By a special adjustment it is possible to get any part desired (Fig. 5).

Two electrodes of the material to be examined are made either by turning down small bars or by dissolving a sample and pressing into tablet electrodes. Part 1 of the slit is exposed with an electrode of pure iron. Parts 2, 4 and 6 with electrodes of the sample and parts, 3, 5 and 7 with electrodes of known concentrations. It is possible to have four of these rows on one plate 9 × 12 cm., i. e., to use 12 known concentrations for comparison. By comparing part 1 with 2 all lines belonging to the non-ferrous metal in question are found. Then, it must be determined where the intensity of these lines is equal to that of one of the known concentrations.

It is useful to take a picture of the wave length scale twice on each plate and the spectrum of mercury for the determination of the exact position of the wave length scales. If any unexpected lines are found it will be easy to predict by means of this arrangement to what elements they must belong.

In order to obtain uniform conditions for developing it is best to use the Glycin stand developer. The plates are automatically developed and ready in $^{1}/_{2}$ hour. If it is desired to have the results very quickly the plate may be developed in Metol-Hydrochinon developer of constant concentration. Using the latter method it is possible to obtain the results in 20 minutes after the start of the test.

If a qualitative determination of an unknown constituent is to be made, the exact position of the wave length scales must first be examined by the Hg spectrum. Eventually a correction must be made. The wave length of the lines may then be found. If possible different concentrations are used and sensitive lines are picked out beginning with the shortest waves. In the Handbook of Loewe[7] the elements corresponding to these last lines can be found. Usually the next sensitive line is also given and the result may, thereby, be checked over the whole spectrum. No other qualitative method is so correct and so easily checked during the examination.

Discussion of the method and its application.

As already mentioned above the method can compete with other quantitative methods only in the range of low concentrations. Yet in this range its speed, accuracy and cleanliness make it quite superior to other methods. The small amount of material needed for a determination gives the method a considerable advantage. Even a completed piece of material may be analyzed without a marked loss of material. The topographic analysis mentioned above may procure evidence as to the presence of solid solutions or eutectics, to homogeneity, etc. These results could never be obtained by metallographic examinations as the concentration of the constituent ranges is too low. The quantitative spectrographic analysis may serve to broaden our knowledge with regard to material defects and for classifying scrap, especially for the production of alloy steels. It may be used for testing ores, fire brick, coal, coke and all materials where small amounts of certain constituents may have a distinct and marked influence.

I do not want to arouse exaggerated hopes. The spectrographic analysis has its limitations as have all analytical methods. I do not doubt though that more application possibilities may be found after the introduction of the spectroscope into our laboratories. I have, therefore, stressed the different possible applications and developments.

Average American Citizen Consuming More Steel

The 1929 per capita average of steel consumption per American citizen has risen to 999 pounds, twice as much as the German used, more than three times that used by the average Frenchman, and nearly 1$^{3}/_{4}$ as much as used by a British subject. These interesting facts were made known through figures compiled by trade agencies and made available at the Bureau of Foreign and Domestic Commerce on January 18, 1930.

Steel production per capita in the United States also showed an increase to 1034 pounds, 72 pounds or 7.4% over the preceding year. The 1929 output equalled the total of the 12 years, 1878–1889, a gain of 39% in 10 years and 75% in 20 years.

Crucible Steel Enlarging Cincinnati Facilities

In furtherance of its vigorous expansion policy, The Crucible Steel Company of America is preparing to desert its present cramped quarters at 209 West Third Street, Cincinnati, and move into a new building which will triple its facilities for doing business in this area.

The new structure, (a substantial building with facades of pressed brick with cut stone trimming) will be located at Spring Grove Avenue and Township Street, and with equipment will involve an investment of approximately $75,000. The contract has been let to The Ferro Concrete Construction Company.

The second floor front of the building will be devoted to offices while the remainder of the structure will be used for warehousing and merchandising purposes. It will be fully equipped with cranes and other modern mechanical means for the handling of steel.

Calendar of Meetings

National Metal Trades Association, Hotel Astor, New York, N. Y., April 16–17.

American Welding Society, New York, N. Y., April 23–25.

National Academy of Sciences, Washington, D. C., April 28–30.

Institute of Metals, Annual May Lecture, London, England, May 7.

American Iron & Steel Institute, Hotel Commodore, New York, N. Y., May 9.

American Institute of Chemists, Annual Meeting, Philadelphia, Pa., May 10.

American Foundrymen's Association, Cleveland, Ohio, May 12–17.

American Society of Mechanical Engineers, Fourth National Aeronautic Meeting, Dayton, Ohio, May 19–22.

Canadian Chemists, 13th Annual Convention, Ottawa, Canada, May 26–28.

American Electrochemical Society, St. Louis, Mo., May 29–31.

American Institute of Chemical Engineers, Book-Cadillac Hotel, Detroit, Mich., June 4–6.

Exposition for Chemical Apparatus, Frankfort, Germany, June 10–22.

Association of Iron & Steel Electrical Engineers, Buffalo, N. Y., June 16–20.

American Railway Association Convention, Atlantic City, N. J., June 18–25.

World Power Conference, Berlin, Germany, June 16–25.

American Society for Testing Materials, Haddon Hall, Atlantic City, N. J., June 23–27.

Society for the Promotion of Engineering Education, Montreal, Canada, June 26–28.

International Exposition at Liége, Belgium, chemical and engineering sessions, Sept. 14–21.

Société de Chimie Industrielle, Liege, Belgium, Sept. 21–27.

National Metal Congress and Exposition, Hotel Stevens, Chicago, Ill., Sept. 22–27.

British Cast Iron Research Association, London, England, Oct. 29.

American Gas Association, Atlantic City, N. J., Oct. 13–17.

Association for the Advancement of Science, Cleveland, Ohio, Dec. 29–Jan. 31, 1931.

Book Reviews

Technische Elektrochemie. By KURT ARNDT. F. Enke, Stuttgart, 1929. $6^1/_2 \times 10$ inches. 708 pages, 438 figs. Price, paper 52 R. M., cloth 55 R. M.

Although this book contains more than 700 pages, it deals sketchily with any one subject because of the vast scope. It deals with electrothermics, fused electrolytes, refining of metals, plating, electrolytes of alkali chlorides, production of inorganic and organic compounds, dry cells, storage batteries, fixed nitrogen and ozone.

Electric steel is covered in $6^1/_2$ pages, including a diagram of a single phase Heroult furnace. Electric brass melting is mentioned only in a couple of footnotes. There is nothing whatever about high-frequency furnaces or their uses.

Much of the information is taken from papers of the vintage of 1900–1910, and while it may still be the last word on the subject in hand, this and the frequent references to German patents make one question whether the information given is fully representative of modern knowledge, and actual practice.

Brief comment is given on analytical methods for many of the products mentioned. The chemistry involved in the various processes is briefly given. The chemist will probably find the book more satisfying than will the metallurgist.

One can find a little about most phases of electrochemistry in the book, and much that is up to date, as well as much that is mainly of historical interest, but the subject is too vast to be dealt with in a single book, or by a single author, with any assurance of adequate treatment. As an introduction to, and a general survey of the subject, it is useful.

It is well printed on good paper. But why any such book is ever put out in paper covers is a conundrum. It starts to come apart before all the pages are cut.—H. W. GILLETT.

Lehrbuch der Metallkunde, des Eisens und der Nichteisenmetalle. By FRANZ SAUERWALD. Julius Springer, Berlin, 1929. Cloth, 462 pages, 399 figs. Price, 29 R. M.

The rapid development of metallurgical research and the vast accumulation of scientific data make it difficult both for the student and the practical man to keep in touch with the whole field of metallurgical investigation. The object of this book is to present in one volume a general picture of the field covered by the science of metals, which is defined in the preface as the science of properties and behavior of metals and alloys with particular respect to their importance during shaping, treating and commercial application. The book is arranged in a systematic manner and general principles rather than details of methods are employed throughout. The author restricts himself to well-founded facts and statements and avoids hypothetical speculations. The added references are skillfully selected from the world's literature preferably citing those publications which in turn collected the most important investigations.

The book is divided into two parts. In the first part we find on 287 pages the fundamentals of metallurgical technology whether pertaining to physical chemistry, radiology and X-ray technique, crystallography, technology of testing materials or to chemistry and to the corrosion of metals. Well-selected examples of all those fields are presented emphasizing and systematically classifying the most recent state of the knowledge so as to obtain information on any special problem within a short time starting from the book and its references.

The second part assembles on 111 pages the particular properties of iron and on 52 pages those of non-ferrous metals. Considering the size of the book, it is obvious that the space devoted to individual subjects must of necessity be limited in order that no phase shall be entirely neglected. The author has achieved this result to a remarkable degree, and the reader is enabled to obtain a very clear picture of the many sides of a problem. Thus the book is a valuable text-book for students as well as a reference book for metallurgists and technologists. The only disadvantage is that the book is in German. One can only regret than an English translation of this well-balanced résumé of metallurgical technology is not available at the present time.—E. FETZ.

Wrought Iron in Architecture. By GERALD K. GEERLINGS. Charles Scribner's Sons, New York, 1929. Cloth, 9 × 12 inches, 202 pages, 324 figs. Price, $7.50.

This volume is the companion book of "Metal Crafts in Architecture: Bronze, Brass, Cast Iron, Copper, Lead and Current Developments." The author collects in one volume a concise history of wrought iron in the various European countries and in the United States, supplemented by illustrations of the most representative work.

The metallurgist and engineer thinks of wrought iron as the material from which pipes, tubes and staybolts are manufactured. Leafing through this volume will dispel this opinion and will give the reader a greater appreciation for this homely metal. In the hands of a craftsman masterpieces are wrought.

The first chapter treats of craftsmanship and the architect's design and drawings, while succeeding chapters deal separately with the ironwork of Italy, Spain, France, the Lombards, England, Germany, American Pre-Twentieth century and the modern. A final chapter is given over to specifications.—RICHARD RIMBACH.

Handbook of Chemical Microscopy. By DRS. E. M. CHAMOT and C. W. MASON. Vol. I. Principles and Use of Microscopes and Accessories, Physical Methods for the Study of Chemical Problems. John Wiley & Sons, 1930. Cloth, $6 \times 9^1/_4$ inches, 474 pages. Price, $4.50.

With the announcement of this book by the nestors of microscopy at Cornell University, one can almost breathe a sigh of relief and say, "Ah—at last it is here for us all!" Few have had the opportunity of studying under Prof. Chamot at Cornell, some few more have been fortunate in having read his "Elementary Chemical Microscopy," but many will be more than fortunate in having this book. The Handbook, while based primarily on the "Elementary Chemical Microscopy" of Dr. Chamot, has been entirely rewritten. So far only the first volume has come from the press. This treats of the principles and use of microscopes and their accessories and physical methods for the study of chemical problems. The second volume will contain chemical methods and inorganic qualitative analyses.

Volume I is divided into 13 chapters and an Appendix. The first 4 chapters deal with the optical systems of the various microscopes on the market, particular attention being given to their use in the chemical laboratory. The fifth chapter treats of laboratory equipment.

The rest of the book covers ultra-microscopy, photomicrography and microprojection, polarizing microscope, chemical crystallography, indices of refraction, particle size determination, and quantitative analyses of heterogeneous mixtures. The Appendix contains a synopsis of laboratory practices in the chemical laboratory of Cornell University.

While, to the reader, Chapter V might seem somewhat misplaced and breaking the continuity of thought between the fourth and sixth chapters, which deal with the technique of the microscope and the interpretation of results, it does seem better placed when one realizes its importance in this position, from a pedagogic viewpoint.

While the book seems to have been written essentially for advanced students, it does have real worth to the industrial chemist who has heard so much about chemical microscopy, but who has not had the time to study it. This one handbook is truly a handbook in the volume of material it contains, its numerous diagrams, its very complete bibliographies and the detail with which each subject is treated. No amount of effort has been spared in arranging the infinite amount of detail in a logical order and then presenting it in an easily assimilable manner. To one not necessarily a chemist, to a bacteriologist, clinical diagnostician, metallurgist or anyone whose daily routine demands an intimate knowledge of the uses of a microscope, although the book treats only of chemical microscopy, it will prove of inestimable value.

We eagerly await the announcement of the second volume.—ARTHUR SCHRODER.

Steel Founders Will Meet in St. Louis

J. E. McCauley, Birdsboro Steel Foundry & Machine Co., Birdsboro, Pa., President S. F. S. A., who presided at the Steel Founders February meeting at the Bellevue-Stratford Hotel, Philadelphia, on the 26th and 27th of February, announced that the May meeting will be held at Cleveland on May 14 at Hotel Hollenden, during the week of the Convention of the American Foundrymen's Association and Exhibition.

The Semi-annual Convention is scheduled for White Sulphur Springs, Greenbrier Hotel, Thursday and Friday, June 26 and 27.

The members in conference reported that the early part of February showed an increase in business over the preceding month. Of the fifty-two foundries present from all parts of the country, thirty-one expressed the opinion that business is improving and twenty-one that business is fair.

J. E. Galvin, President of the Ohio Steel Foundry at Lima, Ohio, stated that "once construction starts in April and May, as it is bound to do, business will start on the upward trend."

"Any firm which has projects in view should go right ahead," he urged, "the government is setting an example. Although I can't believe a lot of money should be spent in useless projects, the majority of those contemplated are worth while."

Foundrymen Go to Cleveland May 12 to 16

Cleveland foundrymen and manufacturers of equipment and supplies in the city have organized a number of committees to arrange for the entertainment of visitors attending the annual convention and exhibition of the American Foundrymen's Association which will be held in Cleveland, May 12 to 16.

EXECUTIVE COMMITTEE: Walter L. Seelbach, general chairman, Forest City, Walworth Run Foundries Co.; Ralph H. West, vice-chairman, West Steel Casting Co.

FINANCE COMMITTEE: Leroy P. Robinson, chairman, Werner G. Smith Co.; George Feiss, vice-chairman, Superior Foundry Co.

PLANT VISITATION COMMITTEE: J. S. Smith, chairman, Smith Facing & Supply Co.

PUBLICITY COMMITTEE: Dan M. Avey, chairman, Penton Publishing Co.

ENTERTAINMENT COMMITTEE: S. C. Vessy, chairman, W. W. Sly Mfg. Co.; B. R. Pearse, Welcoming subcommittee chairman, Atlas Foundry Co.; B. D. Fuller, Golf subcommittee chairman, Whitehead Bros. Co.; J. H. Redhead, Special reception subcommittee chairman, Lake City Malleable Co.

SECRETARY: Frank G. Steinebach, *The Foundry*.

Revere Advertisement Wins Harvard Award

The advertisement of Revere Copper and Brass, Incorporated, entitled "The Smoke Marks Paul Revere's Foundry," received the Harvard award for the advertisement published in 1929 most distinguished for its effective use of typography.

More than 12,000 advertisements of prominent companies were entered in this competition, which is conducted every year by the Graduate School of Business Administration of Harvard University. The prize winning advertisement was the second ever published by Revere Copper and Brass, Incorporated, a consolidation of six old and well-known companies in the copper and brass field. Its national advertising campaign was only begun last November, when the company's name was changed from Republic Brass Corporation to Revere Copper and Brass, Incorporated.

This advertisement was one of a series of six which trace the company's history from the time of Paul Revere, noted patriot and founder of the copper and brass industry in America, to the present-day Revere organization.

Richard Seligman was inducted as President of the Institute of Metals at the Annual General Meeting of the Institute in London on March 12th. He was born in London in 1878, educated at Harrow, and Central Technical College City & Guilds Institute, under Prof. Armstrong; awarded Associateship in 1898. He then studied chemistry at the University of Heidelberg, and transferred to Zurich in 1900, being engaged in research work with Prof. Eugen Bamberger. Returning to Heidelberg he gained his doctorate in 1902. After a period in the Niagara Research Laboratories, N. Y., he became chief chemist of the United States Zinc Company, Pueblo, Colorado. In 1905 commenced the specialization in his main work with his appointment as chief chemist to the British Aluminum Company, which appointment he relinquished in 1909 to form the Aluminum Plant & Vessel Co. Ltd., Wandsworth, London. The activities of this concern have been devoted to the development of aluminum in the service of industry, originally in the welding processes which enabled large scale plant to be devised, and later in the associated technological work involved in its use in the foodstuffs, chemical and other industries.

Reviews of Manufacturers' Literature

In this department we shall list each month a selection of the catalogs, books, treatises and other printed matter issued by manufacturers which, in our judgment should be of interest to the readers of METALS & ALLOYS. *Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter for consideration by the editor of this department are invited to do so, and it is suggested that* METALS & ALLOYS *be placed on the regular mailing list so that advance copies of any material of interest to the metallurgical field may automatically come to this department*—EDITOR.

Tempering.—Leaflet illustrates the application of the Homo method to the production coloring of Link-Belt parts. Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa. Other publications of the same company are: Check Your Pyrometers; The Simple Accurate Way of Recording Refrigerating Temperature; Accuracy Unaffected by Conditions of Service; Temperature Curves That Make Profits for You; A Reliable Pyrometer for Students.

Arc Welding of Cast Iron.—A recent publication on the Arc Welding of Cast Iron. This bulletin points out some of the properties of cast iron and gives a recommended procedure to be followed in arc welding. Arc Welding Data No. 11. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

What Is Petroleum?—This booklet, the first of a series on the fundamentals of the petroleum industry, is distributed by the American Petroleum Institute. The 16-page booklet, with black and white cover design and illustrations, is written in simple non-technical language designed for reading by the layman or student who wishes to obtain an idea of the nature and characteristics of petroleum. A feature of the book is the fact that it was prepared with the cooperation of numerous oil company geologists and technical men, who checked and revised the text in accordance with the latest findings and beliefs. For this reason it probably represents the most recent consensus of opinion on the gelogical history of petroleum available. American Petroleum Institute, New York, N. Y.

Instrument for Recording the Thickness of Sheet Materials.—Leaflet describes and illustrates an instrument for recording the thickness of materials. Bulletin 130, Esterline-Angus Co., Indianapolis, Ind.

The Laboratory.—Volume 3, Number 1 of this house organ contains: an interesting editorial entitled "Time" which has brief historical references to time measurement; a description of a spectroscope. Technical Service Department, Fisher Scientific Company, 711 Forbes St., Pittsburgh, Pa.

Wrought Iron Record.—Volume 1, Number 3 of this very interesting publication contains the following articles: Man's Earliest Use of Iron; "Old Ironsides" Carried Some Real Iron; For Bridges, Wrought Iron Once More; Company Pays 100% Dividend from Sale of Old Pipes; More Historic Iron Nails. Wrought Iron Research Association, Union Bank Bldg., Pittsburgh, Pa.

Pyrometer Recorder.—Folder describes the Model 28 Super Pyrometer Recorder for two, four and six records. Thwing Instrument Company, 3339 Lancaster Ave., Philadelphia, Pa.

Manufacture of Nickel Steel Plate.—A reprint from the Transactions of the American Society of Mechanical Engineers. It deals with the manufacture, rolling and inspection of steels containing 2 and 3% nickel and which is used in boiler construction, and particularly with the manufacture of fairly large plates from $^1/_4 - ^1/_2$ inch in thickness. 8 pages. Nickel Steel Data No. 14. International Nickel Co., Inc., 67 Wall St., New York, N. Y. Other publications of the same company: Buyers' Guide, Nickel Alloy Steel Products, Jan. 1, 1930.

Steel Castings.—Leaflet illustrates the application of steel castings to the manufacture of high pressure valves. Lebanon Steel Foundry, Lebanon, Pa.

Catalog No. 1093.—This publication is devoted to a variety of grinding and polishing machines used extensively in industrial laboratories for preparing metallographic specimens. Further information is given therein relative to accessories for grinding and polishing, such as Emery, Tripoli, Alumina, etc. E. Leitz, Inc., 60 E. 10th St., New York.

The Electric Furnaces.—An interesting 4-page folder outlining three good reasons for the use of Bellevue Electric Furnaces illustrated. Bellevue Industrial Furnaces Company, 2971 Bellevue Avenue, Detroit, Michigan.

Compound Melting Tanks.—4-page reprint bulletin No. 170 describing the "Falcon" Electrically Heated Compound Melting Tank with sectional details illustrations. H. O. Swoboda, Inc., 3400 Forbes St., Oakland Sta., Pittsburgh, Pa.

Properties of Haynes Stellite.—A 32-page treatise giving very interesting and complete details of the hardness of this metal. Also portrays the structure by means of photomicrographs. A very valuable booklet which should be in the hands of all who are interested in metals and their properties. Haynes Stellite Company, Kokomo, Indiana.

Brown Remote Type Instruments.—A 32-page catalog No. 7501 presenting full details of operations and application of this line of instruments. Also shows typical hook-up arrangements with many other details of value. Brown Instrument Co., 4517 Wayne Ave., Philadelphia, Pa.

Densite for Refining Steel.—The 28-page booklet outlines in detail and illustrates through the use of photomicrographs the properties and results of various steels through the use of Densite. Refined Steel Products Co., Clark Bldg., Pittsburgh, Pa.

Copper Molybdenum Pipe.—A 32-page book briefly traces the development of the pipe from early times. It also covers the development of Toncan iron, its advantages as a pipe material, its resistance to rust and corrosion, physical properties, etc. The manufacture of pipe from the open hearth to the finished product is illustrated by photographs. A. I. A. File No. 29B8. Republic Iron & Steel Company, Youngstown, Ohio.

Waste Elimination.—A 16-page booklet entitled, "Stop Waste" was published as a contribution to the continuous campaign for the elimination of waste in American Industry carried on in connection with the movement sponsored by the American Society of Mechanical Engineers with the cooperation of the American Management Association. The booklet presents some of the methods used by Westinghouse in conducting a campaign for waste elimination and prevention. Special Publication 1840-A. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Nitriding of Steel.—"The Homo Method Applied to Nitriding of Steel" is the title of a 12-page bulletin covering the Homo nitriding furnace. A brief introduction explains what nitriding is and what it does. Typical installations of Homo nitriding furnaces are given, diagrams show how the furnace operates, and the advantages are listed. Bulletin No. 950. Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.

Analytical Balances and Weights.—A 36-page bulletin describes the various balances and weights manufactured by Julian H. Becker, Delft, Holland.

Patent Department

Through an arrangement with Mr. W. M. Corse, Metallurgical Engineer, Washington, D. C., who operates a well-known Patent Information Service, we are able to publish every month a list of important patents in the metallurgical field from the United States, Canada and Europe. The following countries will be included in the European listing: England, Germany, France, Switzerland, Denmark, Norway, Sweden and Italy.

If our readers wish more information about any of the patents listed below they can get it by writing to our Patent Department, and mentioning the fact that they have seen the reference in METALS & ALLOYS. *We will be prepared to mail copies of United States Patents to clients within twenty-four hours of date of issue by special arrangement. Photostatic copies, translations of claims and of full text of foreign patents will be supplied if desired.*

This service is furnished under special arrangement with Mr. Corse's organization at most reasonable rates. Full information can be secured by writing to Patent Department, METALS & ALLOYS, *419 Fourth Avenue, New York.*

United States Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Electrolytic cell. P. K. Aubel, Baltimore, Md., assignor to American Smelting and Refining Company, New York, N. Y. No. 1,745,348. Feb. 11, 1928.

Direct production of steel or steel alloys from titaniferous ores and iron sands. F. A. de Silva, Westminster, and C. G. Carlisle, Sheffield, England, No. 1,745,360. July 30, 1927.

Art of annealing. G. S. Evans, Oak Park, Ill., assignor to Griffin Wheel Co. Chicago, Ill. No. 1,745,362. Feb. 6, 1922.

Lead-covering of electric cables and the like by extrusion. E. E. Judge, Gravesend, assignor to W. T. Henley's Telegraph Works Company, Ltd., London, England. No. 1,745,371. Apr. 20, 1929.

Method of annealing pickled sheets. W. E. Caugherty, Natrona, Pa., assignor to Allegheny Steel Company, Brackenridge, Pa. No. 1,745,403. Oct. 1, 1924.

Mold. F. J. Creque, Cuyahoga Falls, Ohio. No. 1,745,408. Mar. 13, 1928.

Method for casting pipes. F. Hulme, Newark, N. J., assignor to J. E. Hubbell, New York, N. Y. No. 1,745,424. Aug. 27, 1925.

Soldering ladle. L. R. Seaborn, Ponca City, Okla. No. 1,745,455. Sept. 25, 1928.

Process for the purification of metals. F. Wever, assignor to Kaiser-Wilhelm Institut für Eisenforschung, both of Düsseldorf, Germany. No. 1,745,464. Jan. 18, 1927.

Pig mold. F. W. Coburn, Birdsboro, Pa., assignor to E. and G. Brooke Iron Company, Birdsboro, Pa. No. 1,745,475. Feb. 10, 1927.

Ring-rolling machine. J. H. Taylor, Oak Park, Ill. No. 1,745,514. Aug. 26, 1924.

Permanent mold for making castings. J. S. Thompson, New York, N. Y., assignor to The American Brake Shoe and Foundry Company, Wilmington, Del. No. 1,745,515. Apr. 9, 1926.

Machine for bending metal plates or sheets. W. R. Hume, Melbourne, Victoria, Australia. No. 1,745,539. May 16, 1928.

Method of making metallic bellows. A. O. Scharer, assignor to The Bishop & Babcock Co., both of Cleveland, Ohio. No. 1,745,585. Sept. 17, 1925.

Non-magnetic material. G. W. Elmen, Leonia, N. Y., assignor to Bell Telephone Laboratories, Inc., New York, N. Y. No. 1,745,612. Nov. 24, 1928.

Machine for testing the bending strength of metal strips. J. H. Nead, R. L. Kenyon and C. W. Rust, assignors to The American Rolling Mill Co., all of Middletown, O. No. 1,745,634. Aug. 25, 1927.

Continuous pickling machine. C. B. Palmer and K. Kronborg, assignors to The American Rolling Mill Co., all of Middletown, Ohio. No. 1,745,636. Nov. 9, 1926.

Iron-carbon alloy. A. Sauveur, Cambridge, Mass., assignor to The American Rolling Mill Co., Middletown, O. No. 1,745,645. June 4, 1925.

Electrolytic cell. F. F. Poland, Baltimore, Md., assignor to American Smelting and Refining Co., New York, N. Y. No. 1,745,688. Feb. 11, 1928.

Bearing metal and method of making same. R. J. Shoemaker, assignor to S. & T. Metal Co., both of Chicago, Ill. No. 1,745,720. Apr. 29, 1927.

Bearing metal. R. J. Shoemaker, assignor to S. & T. Metal Co., both of Chicago, Ill. No. 1,745,721. Sept. 16, 1927.

Method of treating ferrotitanium ores. G. J. Bancroft, Denver, Colo. No. 1,745,732. Feb. 19, 1929.

Manufacture of butt and lap welded tubes. D. W. Chisholm, Glasgow, Scotland, assignor to The Birchfield Engineering Co., Ltd., Cardiff, Wales. No. 1,745,741. Oct. 11, 1926.

Process of producing impact-resisting railroad rails. S. W. Miller, Hollis, N. Y., assignor to The Oxweld Railroad Service Co., by mesne assignments. No. 1,745,806. Nov. 6, 1928.

Spinning ring and traveler. C. F. Merrill, assignor to Draper Corp., both of Hopedale, Mass. No. 1,745,835. July 2, 1929.

Process of making composite metal articles. R. E. Bissell and C. W. Miller. assignors to Thompson Products, Inc., all of Cleveland, O. No. 1,745,886. Dec. 30, 1927.

Apparatus for casting metal articles. J. J. Dimeo, assignor to The Permold Co., both of Cleveland, O. No. 1,745,891. Sept. 11, 1926.

Chromium-coated wire and method of manufacture. H. K. Richardson, Bloomfield, N. J., assignor to Westinghouse Lamp Co. No. 1,745,912, May 3, 1923.

Electrical resistance furnace. P. Schlenker, Baden, Switzerland, assignor to Akt.-Ges. Brown, Boveri and Cie, Baden, Switzerland. No. 1,745,915. Sept. 29, 1927.

Process of treating ores or analogous materials. F. S. Mulock, Brighton, Mass., assignor to United States Smelting, Refining & Mining Co., Portland, Me. No. 1,745,945. Jan. 8, 1924.

Mold. C. R. Harry, assignor to the J. B. Foote Foundry Co., both of Fredericktown, O. No. 1,745,991. Mar. 30, 1927.

Flow pyrometer. A. Schack, Düsseldorf, and M. Wenzl, Oberhausen, Germany, assignors to Siemens & Halske Akt.-Ges., Siemensstadt, near Berlin, Germany. No. 1,746,012. July 2, 1927.

Arc Welding. H. M. Hobart, Niskayuna, N. Y., assignor to General Electric Co. No. 1,746,081. June 29, 1926.

Method and apparatus for electric-arc welding. I. Langmuir, Schenectady, N. Y., and P. P. Alexander, Marblehead, Mass., assignors to General Electric Co. No. 1,746,196. Sept. 5, 1925.

Electric welding. E. Thomson, Swampscott, Mass., assignor to General Electric Co. No. 1,746,202. Aug. 26, 1925.

Method and apparatus for electric-arc welding. E. Thomson, Swampscott, Mass., and P. P. Alexander, Marblehead, Mass., assignors to General Electric Co. No. 1,746,203. Oct. 6, 1925.

Electric welding. E. Thomson, Swampscott, Mass., assignor to General Electric Co. No. 1,746,204. July 18, 1929.

Electric-arc welding. E. Thomson, Swampscott, Mass., assignor to General Electric Co. No. 1,746,205. Sept. 3, 1929.

Method and apparatus for electric arc welding. P. P. Alexander, Marblehead, Mass., assignor to General Electric Co. No. 1,746,207, Dec. 26, 1924.

Electric-arc cutting. P. P. Alexander, Marblehead, Mass., assignor to General Electric Co. No. 1,746,208. Aug. 26, 1925.

Method and apparatus for electric-arc welding. P. P. Alexander, Marblehead, Mass., assignor to General Electric Co. No. 1,746,209. Oct. 7, 1925.

Electric welding. P. P. Alexander, Marblehead, Mass., assignor to General Electric Co. No. 1,746,210. Jan. 10, 1927.

Cathode. B. Bart, East Orange, N. J., assignor to Bart Reflector Co., Inc., Newark, N. J. No. 1,746,211. Dec. 11, 1926.

Clamp for molding machines. W. Lewis, Haverford, Pa., assignor to The Tabor Manufacturing Co., Philadelphia, Pa. No. 1,746,219. Nov. 24, 1928.

Molding machine. J. T. Ramsden, assignor to The Tabor Manufacturing Co., both of Philadelphia, Pa. No. 1,746,224. Nov. 24, 1928.

Flask slide fitting. S. Bona, Bridgeport, Conn. No. 1,746,233. May 3, 1928.

Process for making grinding balls. L. J. Barton, McGill, Nev. No. 1,746,236. Nov. 21, 1927.

Apparatus for and method of making tapered tubular poles. E. W. Riemenschneider, assignor to The Union Metal Mfg. Co., both of Canton, Ohio. No. 1,746,281. July 26, 1927.

Method of making steel castings in permanent molds. J. W. Bettendorf, Bettendorf, Iowa. No. 1,746,300. May 12, 1926.

Permanent mold. J. W. Bettendorf, Bettendorf, Iowa. No. 1,746,301. May 12, 1926 (original), Oct. 8, 1926.

Treatment of copper-rich material. S. I. Levy, London, Eng. No. 1,746,313. Mar. 1, 1928.

Machine for boring out core sand from the bells of cast-iron pipes. D. Giles. Chattanooga, Tenn., assignor to U. S. Cast Iron Pipe and Foundry Co., Burlington, N. J. No. 1,746,346. May 12, 1928.

Process for the improvement of the properties of iron-beryllium alloys. G. Masing, Berlin, and O. Dahl, Berlin-Charlottenburg, Germany, assignors to Siemens & Halske Aktiengesellschaft, Siemensstadt, near Berlin, Germany. No. 1,746,356. Apr. 5, 1928.

Casting Machine. A. W. Morris, D. Hill, and S. P. Wetherill, Jr., Haverford, Pa., assignors to Wetherill-Morris Eng. Co., Philadelphia, Pa. No. 1,746,360. Dec. 11, 1928.

Centrifugal pipe mold. J. H. Uhrig, Beverly, N. J., assignor to U. S. Cast Iron Pipe and Foundry Co., Burlington, N. J. No. 1,746,373. June 8, 1927.

Centrifugal pipe-casting machine. J. H. Uhrig, Beverly, N. J., assignor to U. S. Cast Iron Pipe and Foundry Co., Burlington, N. J. No. 1,746,374. May 18, 1928.

Electric weld remover. R. R. Cravens, Big Spring, Tex. No. 1,746,462, June 18, 1928.

Process for producing cast iron of any desired structure. F. Greiner, Cannstatt/Stuttgart, Germany. No. 1,746,467. Nov. 6, 1926.

Rolling-mill guide. W. C. Loyd, Gary, Ind., and H. G. McIlvried, McCandless Township, Pa., assignors to American Sheet and Tin Plate Co., Pittsburgh, Pa. No. 1,746,483. Apr. 6, 1928.

Hot-mill catcher. A. R. McArthur, Gary, Ind., assignor to American Sheet and Tin Plate Co., Pittsburgh, Pa. No. 1,746,488. Dec 28, 1927.

Continuous wire-drawing machine. R. L. Morgan, Worcester, Mass. No. 1,746,490. Mar. 4, 1924.

Brake drum. R. J. Norton, Washington, D. C. No. 1,746,493. Feb. 2, 1929.

Brake drum. R. J. Norton, Washington, D. C. No. 1,746,494. Feb. 7, 1929.

Apparatus for punching holes in the closed ends of drawn-metal cylinders and the like. G. Rabold, Sr., McKeesport, Pa., assignor to National Tube Co., N. J. No. 1,746,498. Nov. 2, 1926.

Magnetic alloy. W. S. Smith, Benchams, Newton Poppleford, and H. J. Garnett, Sevenoaks, England. No. 1,746,500. May 7, 1927.

Apparatus for handling sheet metal. E. R. Knapp, Summit, N. J., assignor to Copper Plate Sheet and Tube Co., N. Y., N. Y. No. 1,746,536. June 15, 1928.

High silicon and high manganese steel. W. C. Hamilton, E. Chicago, Ind., assignor to American Steel Foundries, Chicago, Ill. No. 1,746,586. Apr. 21, 1927.

Sinuous conveyer. V. A. Fox, assignors to Young Brothers Co., both of Detroit, Mich. No. 1,746,644. June 22, 1928.

Double-deck oven. V. A. Fox, assignors to Young Brothers Co., both of Detroit, Mich. No. 1,746,645. June 22, 1928.

Chemical reagent. F. H. Rhodes, Ithaca, N. Y. No. 1,746,676. July 18, 1929.

Chemical reagent. F. H. Rhodes, Ithaca, N. Y. No. 1,746,677. July 18, 1929.

Chemical reagent. F. H. Rhodes, Ithaca, N. Y. No. 1,746,678. July 18, 1929.

Chemical reagent. F. H. Rhodes, Ithaca, N. Y. No. 1,746,679. July 18. 1929.

Chemical reagent. F. H. Rhodes, Ithaca, N. Y. No. 1,746,680. July 18, 1929.

Flotation apparatus. J. P. Ruth, Jr., Denver, Colo. No. 1,746,682. Oct. 8, 1927.

Blast furnace. H. Koppers, Essen, Germany. No. 1,746,705. Sept. 29, 1922.

Process for making electrolytic iron. R. D. Pike, Piedmont, Calif. No. 1,746,903. Jan. 4, 1926.

Metallurgical furnace. R. D. Pike, Piedmont, Cal. No. 1,746,904. Sept. 3, 1927.

Brake drum. V. Bendix, assignor to Bendix Brake Co., both of South Bend, Ind. No. 1,746,924. Feb. 20, 1929.

Brake drum. V. Bendix, assignor to Bendix Brake Co., both of South Bend, Ind. No. 1,746,925. Feb. 28, 1929.

Recovering metals. R. W. Hyde, Summit, N. J., assignor to Dwight and Lloyd Metallurgical Co., N. Y., N. Y. No. 1,746,945. May 21, 1927.

Sand riddle. G. F. Naab and A. B. Waltz, assignors to the North American Mfg. Co., all of Cleveland, Ohio. No. 1,746,958. May 2, 1927.

Protection of cuprous metals. I. T. Bennett, assignor to T. E. Murray, both of Brooklyn, N. Y. No. 1,746,987. March 6, 1925.

Filler rod for welding and brazing processes. J. B. Green, Chicago, Ill. No. 1,747,000. May 1, 1926.

Electrode composition for electron-discharge devices. S. Dushman, Schenectady, N. Y., assignor to General Electric Co. No. 1,747,061. July 2, 1923.

Electrode composition for electron-discharge devices. S. Dushman, Schenectady, N. Y., assignor to General Electric Co. No. 1,747,062. July 2, 1923.

Electrode composition for electron-discharge devices. S. Dushman, Schenectady, N. Y., assignor to General Electric Co. No. 1,747,063. July 2, 1923.

Electrode composition for electron-discharge devices. S. Dushman, Schenectady, N. Y., assignor to General Electric Co. No. 1,747,064. July 2, 1923.

Heat-treating furnace. Major E. Gates, Terra Cotta, Ill. No. 1,747,067. Oct. 6, 1926.

Silver extraction. E. Haehre, Oslo, Norway, assignor to Thomas Roberts and Co., London, Eng. No. 1,747,072. Feb. 15, 1928.

Method for the manufacture of bodies of great density. M. Pirani, Berlin-Wilmersdorf, Germany, assignor to General Electric Co. No. 1,747,133. May 11, 1928.

Method of hardening metal strips. C. Schumacher, Lynnbrook, N. Y., assignor to Autostrop Patents Corp., Dover, Del. No. 1,747,145. May 3, 1927.

Plate holder for chromium-plating machines. W. S. Eaton, Sag Harbor, N. Y. No. 1,747,165. Jan. 8, 1927.

Process for the production of aluminum-silicon alloys free from carbide. C. von Girsewald, Frankfort-on-the-Main, Germany. No. 1,747,197. May 8, 1926

Cupola Furnace. T. P. Anthony, Edgewater Park, N. J. No. 1,747,208. March 27, 1929.

Continuous-heating furnace. A. Aureli, Cogoleto, Italy, assignor to "Ilva" Alti Forni Fonderie & Acciaerie d'Italia, Genoa, Italy. No. 1,747,209. Dec. 10, 1927.

Casting and chilling mold. D. J. Campbell, Muskegon Heights, Mich. No. 1,747,223. Jan. 17, 1927.

Annealing pot. G. A. Hassel, McKeesport, Pa., assignor to Pittsburgh Steel Foundry Corp., Glassport, Pa. No. 1,747,298. Feb. 1, 1928.

Process of recovery of vanadium from complex solutions. G. S. Tilly, Mill Valley, Cal. No. 1,747,403. June 3, 1927.

Soldering device. D. H. Bottrill, Pointe Claire, Que., Can., assignor to Drysdale & Pease, Montreal, Can. No. 1,747,419. May 28, 1927.

Nozzle for metal-pouring ladles. W. T. Schaup, Swissvale, Pa. No. 1,747,530. April 10, 1928.

Hardening process. A. B. Kinzell, Bayside, N. Y., assignor to Electro Metallurgical Co. No. 1,747,549. June 27, 1928.

Grid-casting machine. A. D. Lund, Minneapolis, Minn. No. 1,747,552. Aug. 17, 1927.

Process of preparing sheaves. A. E. Hansen, Seattle, Wash., assignor to Young Iron Works, Seattle, Wash. No. 1,747,629. Apr. 25, 1927.

Cupola top. C. G. Hawley, Chicago, Ill., assignor to Centrifix Corp., Cleveland, Ohio. No. 1,747,669. Mar. 11, 1926.

Ingot mold with chilled matrix walls and apparatus for making same. J. E. Perry, Sharon, Pa., assignor to Valley Mould and Iron Corp., Sharpsville, Pa. No. 1,747,679. July 3, 1926.

Combined electrode and holder. V. L. Soderberg, Detroit, Mich. No. 1,747,685. June 3, 1927.

Process of treating mixtures of alkali stannates, arsenates, and antimonates. A. E. Hall, Perth Amboy, N. J., assignor to American Smelting and Refining Co., N. Y., N. Y. No. 1,747,709. March 5, 1927.

Tuyère for metallurgical blast furnaces. W. A. Haven, Youngstown, Ohio. No. 1,747,712. March 6, 1925.

Apparatus for reducing ores. G. S. Howell, Seattle, Wash. No. 1,747,716. Nov. 14, 1928.

Casting machine. A. W. Morris, Drexel Hill, and S. P. Wetherill, Haverford, Pa., assignors to Wetherill-Morris Eng. Co., Phila., Pa. No. 1,747,728. Jan. 31, 1929.

Ore-reduction furnace. J. M. Smith, San Francisco, Cal. No. 1,747,740. June 5, 1928.

Electric torch furnace. T. S. Curtis, assignor to The Vitrefrax Corp., both of Huntington Park, Cal. No. 1,747,756. July 30, 1928.

Production of dark oxidic coatings on magnesium and its alloys. B. Jirotka, Berlin, Germany, assignor to the Firm Dr. O. Sprenger Patentverwertung Jirotka m. b. H., Vaduz, Liechtenstein. No. 1,747,776. May 27, 1929.

Apparatus for manufacturing bimetallic billets. H. E. McCrery and A. E. Jesser, Apollo, Pa., assignors to Copper Weld Co., Glassport, Pa. No. 1,747,784. June 23, 1926.

Incorrodible aluminum alloy. H. Schorn, Lausitz, Germany. No. 1,747,796. Sept. 15, 1927.

Magnetic structure. R. M. Bozorth, Short Hills, N. J., assignor to Bell Telephone Lab., Inc., N. Y. No. 1,747,854. June 30, 1928.

Apparatus for hardening products of iron, steel, and other ferromagnetic materials. W. Heidenhain, Hagen, Germany. No. 1,747,934. Dec. 21, 1927.

Apparatus for metal drawing. F. Stachelrodt, Frankfort-on-the-Main, Ger., assignor, by mesne assignments, to Traho Metallic Joint Corp., N. Y. No. 1,747,999. Feb. 16, 1926.

Bearing. E. J. Leach, assignor to Ackermite Co., both of Janesville, Wis. No. 1,748,037. Jan. 16, 1924.

Process of producing bearings. E. J. Leach, assignor to Ackermite Co., both of Janesville, Wis. No. 1,748,038. March 6, 1924.

Flotation apparatus. W. A. Burchart, Joplin, Mo. No. 1,748,107. April 23, 1927.

Rotary retort. W. R. Hume, Melbourne, Victoria, Australia. No. 1,748,178. Sept. 25, 1924.

Soldering flux. C. D. Lawhon, assignor to The Fulton Sylphon Co., both of Knoxville, Tenn. No. 1,748,180. June 3, 1929.

Steel. M. A. Grossmann, Canton, and D. Williams, Massillon, Ohio, assignors to Central Alloy Steel Corp., Massillon, Ohio. No. 1,748,217. July 28, 1927.

Piler for rolled metal. C. H. Hunt, Steubenville, O., assignor to Weirton Steel Co., Weirton, W. Va. No. 1,748,226. Jan. 31, 1928.

Ladle crane. H. M. Lane, Detroit, Mich. No. 1,748,232. Feb. 2, 1929.

Motor-operated casting device. H. A. W. Wood, assignor to Wood Newspaper Machinery Corp., both of New York, N. Y. No. 1,748,268. Aug. 28, 1925.

Machine for subdividing bars while being rolled. J. Henrich, Rheydt, Germany. No. 1,748,289. Sept. 21, 1926.

Apparatus for hardening articles. W. G. Hildorf, assignor to Reo Motor Car Co., both of Lansing, Mich. No. 1,748,290. Oct. 15, 1928.

Magnetic alloy. W. S. Smith, Newton Poppleford, and H. J. Garnett, Sevenoaks, England. No. 1,748,311. July 17, 1928.

Means and method for forming blanks. R. L. Wilcox, assignor to The Waterbury Farrel Foundry and Machine Co., both of Waterbury, Conn. No. 1,748,321. Feb. 13, 1928.

Apparatus for casting metals. W. F. Eppensteiner and H. M. Green, Carteret, N. J., assignors to United States Metals Refining Co., Carteret, N. J. No. 1,748,333. Mar. 26, 1928.

Metal plating. C. L. Peirce, Jr., Pittsburgh, Pa. No. 1,748,363. June 27, 1925.

Process of casehardening ferrous articles. P. A. E. Armstrong, New York, N. Y. No. 1,748,378. Oct. 6, 1928.

Process of smelting ore and other zinc-containing materials. W. Job, Berlin-Dahlem, Germany, assignor to American Lurgi Corp., New York. No. 1,748,450. June 28, 1926.

Electrode holder. C. H. Hollup, Chicago, Ill., assignor to Hollup, Corp- No. 1,748,346. Oct. 11, 1928.

Pickling and cleaning of metals. P. I. Murrill, South Norwalk, Conn., assignor to R. T. Vanderbilt Co., Inc., New York. No. 1,748,494. May 2, 1929.

Electric pipe-welding apparatus. C. Helle, Brunswick, Germany. No. 1,748,551. Mar. 27, 1929.

Method of nitriding steel articles. R. Sergeson, assignor to Central Alloy Steel Corp., both of Massillon, O. No. 1,748,623. Mar. 28, 1929.

Method and apparatus for magnetic prospecting. K. Sundberg, Stockholm, Sweden, assignor, by mesne assignments, to Aktiebolaget Elektrisk Malmletning, Sweden. No. 1,748,659. May 2, 1927.

Electric induction furnace. W. Esmarch, Berlin-Halensee, Germany, assignor to Siemens & Halske Akt.-Ges., Siemenstadt, near Berlin, Germany. No. 1,748,706. Nov. 21, 1928.

Treatment of lead-zinc sulphide ores, mattes, and the like. E. A. Ashcroft. assignor, by mesne assignments, to The Magnesium Company, Ltd., both of London, England. No. 1,748,748. June 28, 1923.

Process of making low-carbon ferro-alloys. F. M. Becket, New York, N. Y., assignor to Electro Metallurgical Co. No. 1,748,750. Feb. 25, 1927.

Friction wire-block clutch mechanism. S. J. Routledge, Ensley, Ala. No. 1,748,796. Sept. 9, 1927.

Electric furnace. A. Stansfield, Westmount, Quebec, Canada. No. 1,748,805. Mar. 22, 1929.

Method of making sectional two-component wire. W. C. Arsem, Schenectady, N. Y., assignor to General Electric Co. No. 1,748,822. Oct. 29, 1926.

Apparatus for applying soft-metal linings to hard-metal tubes. W. R. Smith, Ridgewood, N. J., assignor to Chemical Equipment Manufacturing Co., Paterson, N. J. No. 1,748,851. Jan. 4, 1929.

Machine for guiding cutting burners. W. Eberle, Frankfort-on-the-Main, Germany. No. 1,748,870. Oct. 1, 1928.

Material-feeding device. J. G. Marshall, Niagara Falls, N. Y., assignor to Electro Metallurgical Co. No. 1,748,780. Apr. 30, 1928.

Flux. W. B. Miller, Flushing and A. R. Lytle, Elmhurst, N. Y., assignors to Oxweld Acetylene Co. No. 1,748,785. Aug. 28, 1928.

Resistance welding electrode. R. E. Powell, Westfield, N. J., assignor to Western Electric Co., Inc., New York, N. Y. Reissue Patent No. 17,604 (Original No. 1,673,020, filed May 22, 1926).

British Patents

Subject of Invention, Patentee, Patent No., and Filing Date.

Electrolytic deposition of alloys. B. Leech and F. Hammond. No. 323,765. July 4, 1928.

Method of preparing alkali metals and alkaline earth metals. S. G. S. Dicker (Naamlooze Vennootschap Philips' Gloeilampenfabrieken). No. 323,718. Aug. 3, 1928.

Antifriction bearing-surfaces. J. De Kozlowski. No. 298,485. Oct. 8, 1927.

Process and device for roasting zinc blende. Balz-Erzrostung Ges. No. 309,476. Apr. 11, 1928.

Methods of and furnaces for annealing wire- or band-rings of iron or another metal, by inductive heating. R. Arpi and G. J. M. Dahlquist. No. 323,835. Oct. 24, 1928.

Corrosion-resistant ferrous alloy. J. T. Hay. No. 323,845. Oct. 30, 1928.

Method of coating metal articles with metals. J. Von Bosse. No. 323,847. Nov. 1, 1928.

Presses for drawing sheet metal. A. E. White (Hamilton Press & Machinery Co.). No. 323,884. Dec. 4, 1928.

Electric apparatus for heating articles by induction. P. Viry. No. 302,234. Dec. 12, 1927.

Die-holder for wire-drawing benches. Breguet Frerès. No. 323,946. Dec. 15, 1928.

Guards for presses, stamping-tools, and like machines. J. Broughton. No. 323,950. Feb. 13, 1929.

Cadmium plating. C. H. Humphries. No. 309,071. Apr. 4, 1928.

Inductor furnaces. E. F. Northrup. No. 316,659. Aug. 2, 1928.

Electric induction furnaces. Allmänna Svenska Elektriska Aktiebolaget. No. 310,031. Apr. 21, 1928.

Metal cleaning. G. Jones. No. 324,026. Sept. 7, 1928.

Metal alloy. H. J. Henbrey and C. J. M. Thornhill. No. 324,009. Oct. 11, 1928.

Burner for regenerative furnaces. H. Bangert and G. Huhn. No. 324,157. Nov. 16, 1928.

Method of manufacture of anti-friction alloys. A. E. Ricard and L. Daniels. No. 324,206. January 3, 1929.

Rolling mills. P. Eisner. No. 306,846. Feb. 24, 1928.

Producing highly refractory masses. A. Sprenger. No. 324,312. July 17, 1928.

Manufacture and production of metal carbonyls. J. Y. Johnson (I. G. Farbenindustrie Akt.-Ges.). No. 324,382. Sept. 27, 1929.

Manufacture and production of metallic deposits from metal carbonyls. J. Y. Johnson (I. G. Farbenindustrie Akt.-Ges.). No. 324,363. Oct. 12, 1928.

Reverberatory furnaces. W. F. Sklenar and British Reverberatory Furnaces, Ltd. No. 324,339. Oct 22, 1928.

Electrolytical deposition of chromium. W. G. Poetzsch. No. 299,395. Oct. 25, 1927.

Electric induction furnaces. Siemens and Halske Akt.-Ges. No. 301,894. Dec. 8, 1927.

Autogenous welding and cutting processes. F. Körner. No. 324,449. Nov. 15, 1928.

Annealing or case hardening covers. J. A. Smeeton. No. 324,463. Nov. 22. 1928.

Multiple-hearth roasting-furnaces. A. E. White (Nichols Copper Co.), No. 324,471. Dec. 5, 1928.

Electric induction heating-installations. P. Viry, No. 302,235. Dec. 12, 1927.

Furnaces. British Thomson-Houston Co., Ltd. No. 303,009. Dec. 24, 1927.

Pyrometer. F. C. Whalen and Radiovisor Parent, Ltd. No. 324,500. Jan. 4, 1929.

Fastening of heating-rods in electric furnaces and the like. Siemens-Schuckertwerke Akt.-Ges. No. 305,470. Feb. 4, 1928.

Rolling-mills. Mannesmannrohren-Werke. No. 308,965. Apr. 2, 1928.

Improving the resistance to corrosion of magnesium alloys. I. G. Farbenindustrie Akt.-Ges. No. 316,208. July 25, 1928.

Electrodeposition of metals. Imperial Chemical Industries, Ltd., and J. Hollins. No. 324,589. April 24, 1929.

Oxy-acetylene or like blow-pipes. R. A. Ryan and Thorn & Hoddle, Ltd. No. 324,592. April 27, 1929.

Electric induction furnaces. E. F. Northrup. No. 313,044. June 5, 1928.

Electric furnaces. Birmingham Electric Furnaces, Ltd., & A. G. Lobley. No. 324,609. Dec. 28, 1928.

Flux for tinning and other purposes. W. H. H. Platt. No. 324,611. July 4, 1929.

Manufacture of iron and steel. Vereinigte Stahlwerke Akt.-Ges. No. 295,-022. Aug. 6, 1927.

Method of and apparatus for treating metal sheets. E. Griffiths and E. E. Griffiths. No. 324,679. July 31, 1928.

Treating material containing tin. S. Tamaru and Y. Koizumi. No. 324,685. Sept. 3, 1928.

Method of producing chrome-iron sponge. H. G. Flodin. No. 300,637. Nov. 17, 1927.

Annealing. H. M. Robertson. No. 324,627. Oct. 26, 1928.

Electrically-heated furnaces. Siemens-Schuckertwerke Akt.-Ges. No. 302,-223. Dec. 12, 1927.

Method and device for producing homogeneous metallic coatings and particularly lead coatings. M. U. Shoop. No. 315,343. July 12, 1928.

Electrical induction furnaces. N. R. Davis and Associated Electrical Industries, Ltd. No. 324,789. Jan. 8, 1929.

Cadmium plating. C. H. Humphries. No. 309,072. April 4, 1928.

Light metal alloy. J. Weiss. No. 309,538. April 12, 1928.

Non-corrodible alloy. H. Andre. No. 310,962. May 5, 1928.

Producing an alloy consisting of carbide of tungsten or molybdenum and of a lower melting metal or metalloid. F. Krupp Akt.-Ges. No. 310,885. May 2, 1928.

Induction furnaces heated by high-frequency coils. Heraeus Vacuumschmelze Akt.-Ges. and W. Rohn. No. 324,869. May 1, 1929.

Canadian Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Process of treating tin-bearing ores. H. L. Sulman and H. F. Kirkpatrick, London, England. No. 296,967. May 16, 1927.

Autogenous, manually operatable cutting apparatus. H. Busekist, Kirchen a.d. Sieg, Germany. No. 296,974. Jan. 18, 1929.

Sintering machine. J. R. Linney, Lyon Mountain, N. Y. No. 297,001. Oct. 31, 1928.

Device for separating and concentrating ores. A. W. McTaggart, Anyox, B. C. No. 297,012. July 11, 1927.

Recovery of metals. Guggenheim Bros., New York, N. Y., assignee of P. Robinson, New York, N. Y. No. 297,090. May 16, 1928.

Apparatus for manufacturing welded structures. The Ingalls Steel Products Co., assignee of T. A. Lucy, both of Birmingham, Ala. No. 297,094. Mar. 7, 1929.

Condenser for zinc vapors. The New Jersey Zinc Co., New York, N. Y., assignee of F. G. Breyer, Palmerton, Pa. No. 297,102. July 27, 1927.

Method of reducing zinciferous materials. The New Jersey Zinc Co., New York, N. Y., assignee of F. G. Breyer, Palmerton, Pa. No. 297,103. July 27, 1927.

Reduction of zinciferous materials. The New Jersey Zinc Co., New York, N. Y., assignee of F. G. Breyer, Palmerton, Pa. No. 297,104. July 27, 1927.

Method of introducing gaseous fluids into the charge in rotary furnaces. G. Bojner, Kalstad; and A. H. Pehrson, Granbergsdal, Sweden. No. 297,156. Apr. 22, 1927.

Machine for manufacturing sheet metal tubes. K. Brietenbach, Siegen, Westfalen, Germany. No. 297,173. Sept. 27, 1928.

Press for tubes. R. H. Cowdery, Geneva, Ohio. No. 297,186. Nov. 2, 1928.

Casting machine. N. H. Denner, Lakewood, Ohio. No. 297,188. Mar. 30, 1929.

Radiator forming machine. J. Karamazin, Detroit, Mich. No. 297,213. Mar. 1, 1928.

Production of metal from ores. T. Rowlands, Sheffield, England. No. 297,238. Aug. 16, 1928.

Rolling mill guide. The American Sheet and Tin Plate Co., Pittsburgh, Pa., assignee of W. C. Loyd, Gary, Ind.; and H. G. McIlvried, McCandless Township, Pa. No. 297,251. Oct. 15, 1928.

Zinc roasting apparatus. Balz-Erzröstung G. m. b. H., Gleiwitz, assignee of GaBalz, Tübingen, Germany. No. 297,254. Oct. 25, 1928.

Method of storing alkali metals. The Canadian General Electric Co., Toronto, Ont., assignee of D. H. Brophy, and W. A. Ruggles, Schenectady, N. Y. No. 297,265. July 3, 1928.

Apparatus for electrolytically depositing metal on metal tubes. J. Stone & Co., Ltd., Deptford, Kent, England, assignee of F. G. Martin and W. Ramsay, Birkenhead, Cheshire, England. No. 297,348. Mar. 23, 1928.

Zinc reduction furnace. A. Roitzheim and W. Remy, both of Berlin-Oberschoneweide, Germany. No. 297,388. Dec. 27, 1926.

Apparatus for separating materials of different specific gravity. H. M. Chance, Philadelphia, Pa. No. 297,405. Apr. 12, 1929.

Method of soldering radiators. G. W. Cristoph, Warehouse Point, Conn. No. 297,406. Oct. 2, 1928.

Extraction of metallic values from ores. F. Dietzsch, Kingston-on-Thames, Surrey, England. No. 297,408. Nov. 2, 1927.

Treatment of ores and metallurgical products. Fried. Krupp Grusonwerk. Akt.-Ges., Magdeburg-Buckau, assignee of F. Johannsen, Magdeburg, Germany. No. 297,475. Feb. 4, 1929.

Treatment of ores and metallurgical products. Fried. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, assignee of F. Johannsen, Magdeburg, Germany. No. 297,476. Feb. 4, 1929.

Treatment of ores and metallurgical products. Fried. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, assignee of F. Johannsen, Magdeburg, Germany. No. 297,477. Feb. 4, 1929.

Method of spot electroplating. The Technidye Corporation, assignee of J. A, Flanzer, both of New York, N. Y. No. 297,499. Mar. 19, 1928.

Method of and apparatus for annealing coiled metals. C. J. Brown, Donora, Pa. No. 297,517. Sept. 10, 1928.

Method of producing ferrosilicon. H. G. Flodin, Stockholm, Sweden. No. 297,544. Feb. 25, 1928.

Apparatus for welding wheels to rims. The Budd Wheel Co., Philadelphia, Pa., assignee of C. L. Eksergian, Detroit, Mich. No. 297,594. Mar. 20, 1929.

Wheel welding machine. The Budd Wheel Co., Philadelphia, Pa., assignee of J. W. Hughes, Detroit, Mich. No. 297,595. Mar. 20, 1929.

Control system for rolling mills. The Canadian Westinghouse Co., Ltd.. Hamilton, Ont., assignee of P. McShane, Pittsburgh, Pa. No. 297,605. Jan. 18, 1929.

Laboratory muffle. The Carborundum Co., Niagara Falls, N. Y., assignee of E. B. Metuchen, N. J. No. 297,606.

Multiple wire-drawing machine. Drahtindustrie Peter Darmstadt & Co. G.m.b.H., Frankfurt a.M., assignee of P. Darmstadt, W. Stegman, and V. Weil, all of Fechenheim, near Frankfurt a.M., Germany. No. 297,610. July 4, 1928.

Bearing metal (Cd-Cu-Mg). The Electrolytic Zinc Company of Australasia, Ltd., Melbourne, Victoria, Australia, assignee of R. T. D. Williams, R. Sussex, and J. W. Ross, Hobart, Tasmania, Australia. No. 297,611. Aug. 10, 1928.

Furnace for treating refractory ores containing precious metals. The Evans Ore Reduction Co., assignee of W. B. Evans, both of Wilderness, Va. No. 297,612. Jan. 7, 1929.

Chaplet. The Fanner Manufacturing Co., Cleveland, Ohio., assignee of C. G. Raible, Shaker Heights, Ohio. No 297,613. April. 13, 1929.

Apparatus for forming briquettes. The Fernholtz Machine Manufacturing Co., Ltd., assignee of C. W. Fernholtz, both of Los Angeles, Calif. No. 297,614. Feb. 26, 1929.

Danish Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Process for making a magnetic material containing nickel and iron. Electrical Research Products, Inc., New York, N. Y. No. 41,450 (Addition to No. 38,799). Apr. 28, 1925.

Electric welding apparatus. Steel & Tubes, Inc., Cleveland, Ohio. No. 41,528. Mar. 1, 1923.

Process for impregnating metals or other suitable materials with aluminum or aluminum alloys. The Expanded Metal Co., Westminster, London England. No. 41,554. Feb. 26, 1927.

French Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Transmission for machines having a wide range of power consumption, such as rolling mills. Berliner Maschinenbau Akt.-Ges. vormals Schwartzhoff & A. Huwiler. No. 678,903. July 23, 1929.

Machine for bending tubing and pipes. C. Laurent. Addition Patent No. 36,086. (First addition to Patent No. 653,158.) Nov. 9, 1928.

Treatment of mineral substances such as ores. Société Sobanski & Dunikowski (assignee of Z. Dunikowski). No. 678,564. Nov. 2, 1928.

Iron-silicon alloy containing at least 10% silicon. Fried. Krupp Akt.-Ges. No. 678,708. July 17, 1929.

Process for making metals and alloys containing hydrocarbons. Bayerische Metallwerke Akt.-Ges. No. 678,784. July 19, 1929.

Core impermeable to gases. A. Stahn. No. 678,821. July 22, 1929.

Antifriction alloy. A. Ricard. No. 678,862. July 22, 1929.

Process for casting iron, permitting the production of the desired grain structure in cylinder blocks and mechanical castings in general. E. Mayer and L. Mayer. Addition Patent No. 36,077. (First addition to Patent No. 656,051.) Nov. 3, 1928.

Process for cleaning metallic objects. Société Hahn & Kolb. No. 678,879. July 23, 1929.

Improvements to protective devices for electric furnaces and other apparatus. Compagnie Française pour l'Exploitation des Procédés Thomson-Houston. No. 678,691. July 18, 1929.

Improvements to induction furnaces. E. F. Northrup. No. 678,729. July 18,1929.

Rotary apparatus with controllable current consumption, for chromium plating. S. Dreyfus. No. 678,720. July 18, 1929.

Improvements to electrode holders for electric furnaces. Compagnie des Forges et Aciéries de la Marine et d'Homécourt. No. 678,964. Nov. 20, 1928.

Producer-heated industrial furnace with heat recuperator. Société Fourment & Laduree. No. 678,937. Nov. 15, 1928.

Process for the protection of aluminum, magnesium and their alloys against the action of corrosive agents. C. Boulanger. No. 679,011. Nov. 10, 1928.

Improvements to open-hearth furnaces. Terni Società per l'Industrie & l'Electricita. No. 679,224. July 24, 1929.

Process and connections for electric resistance welding. J. Achard. No. 679,033. Nov. 26, 1928.

Process for the surface coating of iron and steel objects. Société Continentale Parker. No. 679,083. Dec. 3, 1928.

Process for drawing hollow metallic bodies. Rheinische Metallwaren und Maschinenfabrik. No. 679,273. July 25, 1929.

Improved centrifugal machine for the manufacture of metal pipes. Société Anonyme des Hauts-Fourneaux & Founderies de Pont-à-Mousson. No. 679,351. Dec. 10, 1928.

Regulating device for automatic arc welding machines. R. Sarrazin. Addition Patent No. 36,124. (Second addition to Patent No. 617,597.) Nov. 17, 1928.

Improvements to electric furnaces of the induction type. E. F. Northrup. No. 679,239. July 24, 1929.

Special steel, particularly for the manufacture of rails and similar objects. P. P. Marthourey. No. 679,357. Dec. 11, 1928.

Process and apparatus for granulating ores. Société Anonyme La Nouvelle Montagne. No. 679,397. June 19, 1929.

Process and apparatus for treating sheet metal, especially applicable to apparatus in which sheets are annealed in a continuous operation. E. Griffiths and E. E. Griffiths. No. 679,414. July 26, 1929.

Process for making tools of homogeneous alloys having great hardness. Fried. Krupp Akt.-Ges. No. 679,531. July 30, 1929.

Process for making an alloy of iron and aluminum. British Dominions Feralloy, Ltd. No. 679,626. July 31, 1929.

Improvements in the welding of nickel and of alloys having a high nickel content. Société La Soudure Autogène Française. No. 679,359. Dec. 11, 1928.

Apparatus for feeding metal in the centrifugal casting of hollow bodies having the form of a solid of revolution. A Possenti, and C. Scorza. No. 679,422. July 27, 1929.

Method of making welded joints in alloys of iron and steel. Fried. Krupp Akt.-Ges. No. 679,482. July 29, 1929.

Method of making welded joints. Fried. Krupp Akt.-Ges. No. 679,483. July 29, 1929.

Welding wire or rod for welding iron alloys or steel containing copper. Fried Krupp Akt.-Ges. No. 679,536. July 30, 1929.

Apparatus for registering the quotient $dt/d\theta$ of heated or cooled metals and alloys. E. Schwarzkopf. No. 679,524. July 29, 1929.

Method of obtaining metallic carbonyls. I. G. Farbenindustrie Akt.-Ges. No. 679,542. July 30, 1929.

Pulverizing mill for the preparation of coal or other ores. R. Gendre and P. Terlin. No. 679,811. Dec. 20, 1928.

Method and apparatus for electro-magnetic subterranean prospecting. Société de Prospection Electrique (Procédés Schlumberger). No. 679,817. Dec. 21, 1928.

Method of making converter bottoms. Mannesmannröhren Werke and J. Postinett. No. 679,719. Aug. 2, 1929.

Zinc-base alloy capable of being worked mechanically to give fabricated products having special physical properties. The New Jersey Zinc Co. No. 679,727. Aug. 2, 1929.

Converter bottoms. Mannesmannröhren Werke. No. 679,933. Aug. 6, 1929.

Portable apparatus for changing tuyères and tuyère pipes. Vereingte Stahlwerke Akt.-Ges. No. 679,959. Aug. 6, 1929.

Process for treating ores, mining products and the like. Metallgesellschaft Akt.-Ges. No. 679,972. Aug. 7, 1929.

Process of fusion electrolysis. Hirsch Kupfer und Messingwerk Akt.-Ges. No. 679,983. Aug. 7, 1929.

Cupola. P. Marx. Addition Patent No. 36, 169 (First addition to No. 663,942.) Nov. 30, 1928.

Pressure-resistant metallic vessel. Allgemeine Elektricitäts Ges. No. 679,726. Aug. 2, 1929.

Process for obtaining fabricated zinc products having a superior resistance to cold flow. The New Jersey Zinc Co. No. 679,728. Aug. 2, 1929.

Process for improving the physical properties of a fabricated zinc product made of a zinc-base alloy. No. 679,729. Aug. 2, 1929.

Powder for welding aluminum and its alloys. J. F. Lenssens. No. 679,814. Dec. 21, 1928.

Process for making bearing linings of sheet metal. The Cleveland Graphite Bronze Co. No. 679,952. Aug. 6, 1929.

Improvement in the impregnation of carbon electrodes. Bozel Maletra, Société Industrielle Produits Chimiques. No. 679,816. Dec. 21, 1928.

Method of preparing metals in a state of fine subdivision. I. G. Farbenindustrie Akt.-Ges. No. 679,699. Aug. 2, 1929.

Machine for bending and hardening spring leaves. Akt.-Ges. A. Hering. No. 680,044. Aug. 7, 1929.

Blower for ore-treating furnaces. E. Somoza. No. 680,263. Aug. 13, 1929.

Improvements to rolling mill housings. J. Roux. No. 680,010. June 14, 1929.

Process for treating iron baths in steel production furnaces. Fried. Krupp Akt.-Ges. Friedrich Alfred Hütte. No. 680,154. Aug. 10, 1929.

Process for treating metals. H. H. Stout. No. 680,194. Aug. 12, 1929.

Improvements in the thermal refining of copper. H. H. Stout. No. 680,195. Aug. 12, 1929.

Refining gray iron castings and process for obtaining this cast iron. B. Vervoort. No. 680,250. Aug. 13, 1929.

Process for utilizing ores containing copper and zinc. Metallgesellschaft Akt.-Ges., and Hochofenwerk Lubeck Akt.-Ges. No. 680,257. Aug. 13, 1929.

Device applicable to rolling mills provided with guides. Aktie-bolaget Svenska Kullagerfabriken. No. 680,391. Aug. 17, 1929.

Process and device for the rapid shaping and drawing of welded tubing and similar objects. K. Breitenbach. No. 679,995. Sept. 21,1928.

Method of introducing metal stock into a skew rolling mills and device used therefor. Vereinigte Stahlwerke Akt.-Ges. and L. Klein. No. 680,262. Aug. 13, 1929.

Drive for the pinions of skew rolling mills. H. Esser. No. 680,264. Aug. 13, 1929.

Process for casting light metals, particularly magnesium and its alloys in sand molds. I. G. Farbenindustrie Akt.-Ges. No. 680,321. Aug. 14, 1929.

Method of and apparatus for lining hollow bodies, particularly centrifugal casting molds with foundry sand or similar material. A Possenti and C. Scorza. No. 680,358. Aug. 16, 1929.

Process for the aluminothermic welding of sections to heavy pieces having a large surface. Elektro-Thermit G. m. b. H. No. 680,438. July 17, 1929.

Improvements to the feed mechanism of welding machines. Compagnie Francaise pour l'Exploitation des Procédés Thomson-Houston. Addition Patent No. 36, 182. (First addition to No. 666,194.) Nov. 28, 1928.

Process for making metallic coatings. T. Liban. Addition Patent No. 36,224. (First addition to No. 620,770.) Dec. 17, 1928.

Improvements to electric furnaces. Birmingham Electric Furnaces Ltd. & A. G. Lobley. No. 680,381. Aug. 16, 1929.

Improvements to refractory materials and processes for making them. Harbison Walker Refractories Co. No. 680,151. Aug. 9, 1929.

German Patents

Subject of Invention, Pantentee, Patent No., and Filing Date.

Device for obtaining and maintaining a uniform thickness of material on the screens of settling machines. E. Baum, Herne i. W., Germany. No. 491,209. Apr. 21, 1929.

Apparatus for the separation of foreign bodies of higher density from bulk material. Fried Krupp Grusonwerk Akt.-Ges., Madgeburg-Buckau, Germany. No. 491,488. Feb. 24, 1928.

Process for classifying bodies having different electrical or magnetic properties, especially mining products. Fried. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, Germany. No. 491,400. June 1, 1928.

Process for working up ores, minerals, especially complex ores and other floatable substances and mixtures of substances. Erz.-u.Kohle-Flotation G. m. b. H., Bochum, Germany. No. 491,289. May 10, 1928.

Method of operating hot draw benches for drawing tubing. Pressund Walzwerk Akt.-Ges., Reisholz, Germany. No. 491,290. Jan. 21, 1925.

Backing-roller bearing for sheet-straightening machines. Maschinenfabrik Fr. W. Schnutz, Weidenau, Sieg., Germany. No. 491,083. Aug. 29, 1928.

Tubing mill for simultaneously rolling and flanging tubing. E. Möhrlin G. m. b. H., Stuttgart, Germany. No. 491,192. Mar. 11, 1924.

Tuyère for blast furnaces. W. A. Haven, Youngstown, Ohio. No. 491,494. Mar. 30, 1927; in the United States Mar. 29, 1926.

Process for the direct production of metals, particularly iron. B. Young, Frankfurt A.M., Germany. No. 491,227. (Addition to Patent No., 482,204.) Dec. 14, 1928.

Process for the production of tough non-breakable chilled iron castings. W. Clever, Zeitz-Aue, Germany. No. 491,228. Jan. 8, 1927.

Device for use in operating electric annealing furnaces. Akt.-Ges. Brown, Boveri & Cie., Baden, Switzerland. No. 491,239. Nov. 1, 1926.

Electric induction furnace. Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. No. 491,392. June 8, 1927; in the United States June 5, 1926.

Tilting high-frequency induction furnace. Kaiser-Wilhelm-Institut für Eisenforschung e. V., Düsseldorf, Germany. No. 491,393. Jan. 28, 1926.

Process for making welding electrodes. F. Dworzak, Wien, Austria. No 491,511. (Addition to Patent No. 488,815.) May 25, 1928.

Working up ores, smelter products and the like. Metallgesellschaft A. G., Frankfurt A.M., Germany. No. 491,357. Aug. 9, 1928.

Process for the production of copper alloys composed of copper, cadmium and magnesium. O. von Rosthorn, Miesenbach, Lower Austria. No. 491,438. May 27, 1926.

Copper-beryllium alloy. Siemens & Halske Akt.-Ges., Berlin-Siemenstadt, Germany. No. 491,358. Apr. 14, 1927.

Process for the electrolytic production of metals. H. C. Harrison, New York, N. Y. No. 491,254. Feb. 6, 1926; in the United States May 21, 1925.

Gas soldering iron. J. Gysels, San Francisco, Calif. No. 491,370. July 10, 1928.

Welder joint between the end and side of a cylindrical tank. H. Canzler, Düren, Rhld., Germany. No. 491,371. Apr. 7, 1929.

Welding pieces together by the interposition of highly heated steel which has been melted in an electric furnace. Elektro-Thermit G. m. b. H., Berlin-Tempelhof, Germany. No. 491,536. Apr. 18, 1929.

Making a welded seam in copper tanks and the like. W. Schmidding, Köln-Mansfield, Germany. No. 491,372. Sept. 13, 1928.

Automatic, electrically-driven torch cutting machine. Messer & Co., G. m. b. H., Frankfurt a.M., Germany. No. 491,373. Jan. 6, 1929.

Process for making multi-layer metals, especially with a top layer of noble metal. Fr. Kammerer A. G., and E. Kammerer, Pforzheim, Germany. No. 491,374. (Addition to Patent No. 487,410.) Aug. 21, 1927.

Apparatus for the wet dressing of ores and fuels. T. M. Davidson, Hatch End, England. No. 491,694. Nov. 18, 1925; in Great Britain Jan. 1, 1925.

Magnetic separator. Fried. Krupp Grusonwerk Akt.-Ges., Madgeburg-Buckau, Germany. No. 491,695. Aug. 24, 1928.

Arrangement for diminishing the idling time of tube rolling mills by mechanically advancing the hollow billet and by mechanically interchanging the rolling mandrels. J. Sommer, Essen, Germany. No. 491,869. Oct. 9, 1928.

Roller bed with two or more side-by-side runways for the rolled material. Fried. Krupp Grusonwerk Akt.-Ges., Madgeburg-Buckau, Germany. No. 491,870. (Addition to Patent No. 470,535.) May 25, 1929.

Wire-cleaning apparatus. Friedrich Köster, Oberkassel, near Bonn, Germany. No. 492,056. Aug. 31, 1928.

Device for tube-drawing benches. E. Bovermann, Mülheim, Ruhr-Speldorf, Germany. No. 492,057. Dec. 25, 1927.

Straightening or upsetting bench. W. Huppert, Neschwitz a.d. Elbe, Czechoslovakia. No. 491,968. July 21, 1928.

Electrically heated crucible furnace, particularly a salt-bath furnace with suspended crucible. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 491,600. May 22, 1928; in the United States June 4, 1927.

Furnace for the continuous heat treating of steel parts. K. Vossloh, Werdohl i. W., Germany. No. 491,601. Sept. 18, 1926.

Electric spot-welding machine. Allgemeine Elektrizitäts Gesellschaft, Berlin, Germany. No. 492,087. Mar. 14, 1926.

Process for lap-welding sheet metal by means of current induced therein. A. Pfretzschner G.m.b.H., Pasing, near München, Germany. No. 491,998. July 14, 1928.

Core-molding machine. Sté. Ame des Fonderies Samson, Huy, Belgium. No. 491,900. May 10, 1928.

Introduction of air into the roasting chambers of mechanical muffle roasting furnaces. Balz-Erzröstung G.m.b.H., Gleiwitz, Germany. No. 491,729. Sept. 30, 1928; in Austria Oct. 31, 1927.

Recovery of volatile metals from slags and the like. Anaconda Copper Mining Co., New York, N. Y. No. 491,625. July 22, 1927.

Recovery of noble metals, particularly platinum metals. H. Schuchard, neé Heinze, Berlin-Wilmersdorf, Germany. No. 491,730. Nov. 28, 1926.

Inoxidizable alloy. C. Contal, St. Cloud, Seine, France. No. 491,815. June 30, 1929.

Aluminum alloy. Th. Goldschmidt Akt.-Ges., Essen a. d. Ruhr, Germany. No. 492,047. July 21, 1922.

Potassium of liquid potassium-sodium alloys. L. Hackspill and E. Riuck, Strassburg, France. No. 491,626. June 27, 1928; in France Aug. 8, 1927.

Process for producing highly polished surfaces on gold and fine silver ware. M. Holzer, Pforzheim, Germany. No. 492,022. June 3, 1927.

Process for removing lead deposits from iron or steel objects, particularly for cleaning gun barrels. G. Halbe, Hamburg, Germany. No. 491,747. June 10, 1928.

Welding burner. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 492,560. Aug. 31, 1926.

Billet delivery device for pilger rolling mills. R. Traut, Mülheim, Ruhr, Germany. No. 492,147. Jan. 17, 1929.

Machine for making autogenously welded tubing. O. Meyer-Keller & Cie., Luzerne, Switzerland. No. 492,491. July 28, 1927.

Method of preventing the sticking and scaffolding in blast furnaces, or similar shaft furnaces. Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. No. 492,415. Sept. 17, 1927.

Cooling means for refractory brickwork, particularly that of open-hearth, welding and heating furnaces. P. Kühn, Niederschilden, Kr. Siegen, Germany. No. 492,432. Mar. 26, 1927.

Resistance heating device, particularly for furnaces. F. W. Tabb, Paris France. No. 492,444. Mar. 10, 1928; in Belgium Mar. 18, 1927.

Hollow electrode for electric furnaces. A. Walter, Mückenberg, Kr. Liebenwerda, N.-L., Germany. No. 492,343. Jan. 23, 1927.

Tilting electric furnace. Demag Akt.-Ges., Duisburg, Germany. No. 492,591. Jan. 22, 1929.

Welding tongs for electric arc welding, with two electrodes which are movable toward each other. E. V. Gibbons, Boulder, Colo. No. 492,272. July 12, 1927; in the United States July 24, 1926.

Method of making heating resistances. Elektroterm Akt.-Ges., Schaffhausen, Switzerland. No. 492,339. (Addition to Patent No. 481,796.) Apr. 4, 1928.

Process for cooling slag and utilizing the heat of the slag for preheating the blast of cupola furnaces. F. Schinker, Goslar, Harz, Germany. No. 492,495. Mar. 29, 1927.

Composite cast body with metal core. J. C. Störring & Cie., Voerde, Kr. Schwelm, Germany. No. 492,456. June 14,1928.

Improvement of copper-silicon alloys. M. G. Corson, Jackson Heights, N. Y. No. 492,460. Sept. 30, 1927; in the United States Oct. 4, 1926.

Production of objects which are to be exposed to great variations of temperature. The International Nickel Co., Inc. No. 492,461. Mar. 18, 1926; in the United States Mar. 31, 1925.

Apparatus for determining the ash content of coal or the gangue content of of simple ores and the like. No. 492,608. Feb. 17, 1926.

Sulphur-determination apparatus for iron, steel and the like. E. Greiner, Düsseldorf, Germany. No. 492,609. June 28, 1928.

Process for metal-coating electrically non-conducting materials, such as cellulose ester films. M. O. Wien, Austria. No. 492,621. Sept. 9, 1926; in Hungary Sept. 25, 1926.

Apparatus for measuring the current density in electrolytic baths. Langbein-Pfanhauser-Werke Akt.-Ges., Leipzig, Germany. No. 492,535. Oct. 28, 1927.

Forging machine. Schiess-Defries Akt.-Ges., Düsseldorf, Germany. No. 492,121. July 22, 1928.

Production of welded joints in steel apparatus. Deutsche Bergin Akt.-Ges. für Kohle- und Erdölchemie, Heidelberg, Germany. No. 492,381. Oct. 29, 1927.

Process for removal of iron from materials containing iron. I. G. Farbenindustrie Akt.-Ges., Frankfurt a. M., Germany. No. 492,557. Oct. 5, 1924.

Current washing apparatus for coal and other minerals. A. France, Lüttich, Belgium. No. 493,108. Aug. 21, 1927; in Belgium Feb. 24, 1927.

Classifying device for coal and other minerals. E. Hodeige, Jemeppe-sur-Meuse, Belgium. No. 493,109. Dec. 15, 1927; in Belgium Dec. 15, 1926.

Device for separating heavier bodies from bulk material. Fried. Krupp Grusonwerk Akt.-Ges., Madgeburg-Buckau, Germany. No. 492,671. (Addition to Patent No. 491,488.) Apr. 29, 1928.

Froth flotation machine. Minerals Separation Ltd., London, England. No. 493,110. Feb. 5, 1926; in Great Britain Mar. 20, 1925.

Process for cold rolling light metal sheets. J. Bargou, Stuttgart, Germany. No. 492,826. (Addition to Patent No. 481,809.) Oct. 2, 1926.

Rolling mill. R. Kronenberg, Haus Kronenberg, Post. Immigrath, Germany. No. 492,827. (Addition to Patent No. 449,011.) Jan. 30, 1929.

Rolling mill. R. Kronenberg, Haus Kronenberg, Post Immigrath, Germany. No. 492,828. (Addition to Patent No. 449,011.) Apr. 18, 1929.

Device for turning over round objects especially in rolling mills. Demag Akt.-Ges., Duisburg, Germany. No. 492,829. Mar. 26, 1929.

Cooling bed. L. Löwy, Düsseldorf, Germany. No. 492,830. Mar. 5, 1929; in the United States May 4, 1928.

Device for turning over metal billets, especially in rolling mill installations. Scholemann Akt.-Ges., Düsseldorf, Germany. No. 492,831. May 2, 1929.

Delivery guide for cold rolling mills. W. E. Watkins, New York, N. Y. No. 492,832. Oct. 12, 1928.

Bending rolls for making tubular objects. W. R. Hume. Melbourne, Australia. No. 493,019. May 25, 1928.

Mandrel guide for presses for extruding metal tubing. A. Kreuser G.m.b.H Hamm -.W., Germany. No. 493,020. May 12, 1927.

Hydraulic cutting device for cutting off waste ends, for vertical lead cable presses. Fried. Krupp Grusonwerk Akt.-Ges., Madgeburg-Buckau, Germany. No. 492,958. Feb. 16, 1929.

Baking electrodes and other artificial carbon bodies. L. Riedhammer, Nürnberg, Germany. No. 492,678. Feb. 12, 1928.

Process for producing hafnium or hafnium compounds from mixtures of hafnium and zirconium compounds. Deutsche Gasglühlicht-Auer-Gesellschaft m.b.H., Berlin, Germany. No. 492,754. July 27, 1923.

Magnetic alloy, especially for loading telegraph and telephone cables. W. S. Smith, Newton Poppleford, Devonshire; and H. J. Garnett, Sevenoaks, Kent, England. No. 492,909. May 18, 1927; in Great Britain July 27, 1926.

Automatic regulating device for the electrodes of electric melting furnaces. Demag Akt.-Ges., Duisburg, Germany. No. 492,683. (Addition to Patent No. 484,914.) June 24, 1926.

Method of making castings, particularly wheels for railroad rolling stock. J. C. Davis, Chicago, Ill. No. 492,977. Mar. 17, 1923.

Rotary apparatus for the blast-roasting or sintering of ores. National Processes Ltd., London, England. No. 492,848. Jan. 13, 1929; in Great Britain July 21, 1928.

Working up sulphidic ores and metallurgical products. Fried. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, Germany. No. 492,697. (Addition to Patent No. 475,115.) July 13, 1926.

Production of bearing metals. R. Blasberg, Mersheid, Ohligs, Rhld., Germany. No. 492,698. Dec. 30, 1928.

Slow-tarnishing noble alloy of silver. Verein für die Probier- und Forschungsanstalt für Edelmetalle e. V., Schwäbisch Gmünd, Germany. No. 492,779. July 30, 1927.

Process for producing metals and alloys in the electric furnace. T. R. Haglund, Stockholm Sweden. No. 492,947. Jan. 24, 1928; in Sweden Feb. 1, 1927.

Electrolytic detinning process. The Vulcan Detinning Co., Sewaren, N. J. No. 492,790. Apr. 14, 1927; in the United States Apr. 14, 1926.

Process for the production of metallic coatings on objects made of aluminum or magnesium-free aluminum alloys. Dr. Otto Sprenger Patentverwertung Jirotka m.b.H., Vaduz, Liechtenstein. No. 492,707 (Addition to Patent No. 442,766.) Mar. 16, 1928.

Hard solder, especially for gray cast iron, cast steel, other varieties of iron and other metals. Metallgesellschaft Akt.-Ges., Frankfurt a.M., Germany. No. 492,666. Feb. 19, 1927.

Welding flux for magnesium and its alloys. G. Michel, Bagneux, Seine, France. No. 492,952. Dec. 31, 1924.

Swedish Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Process for treating magnetic material. Electrical Research Products, Inc., New York, N. Y. No. 68,907. Mar. 31,1921. Priority date: July 24, 1926.

Process for the production of rolled steel members. N. Das Chopra and F. J. Bullen, London, England. No. 68,908. Dec. 22, 1926. Priority date: Jan. 2, 1926.

Aluminum alloys. Metallbank und Metallurgische Gesellschaft A. G. Frankfurt a.M., Germany. No. 68,921. Mar. 31, 1925.

Copper alloys and method of producing the same. M. G. Corson, Jackson Heights, N. Y. No. 68,922. July 31, 1926.

Process for the production of magnesium. M. N. Lacell, London, England. No. 68,923. Feb. 21, 1927. Priority date: Mar. 26, 1926.

Construction of welding machine. Svenska Aktiebolaget Gasaccumulator, Stockholm, Sweden. No. 68,986. July 13, 1926.

Process for the production of sponge iron. A. H. Pehrson, Granbergsdal, Sweden. No. 69,015. Oct. 2, 1922.

Alloy. T. D. Kelly, London, England. No. 69,016. Aug. 26, 1927. Priority date: Sept. 4, 1926.

Process for the production of self-baking electrodes. Det Norske Aktieselskab for Elektrokemisk Industrie, Oslo, Norway. No. 69,024. Sept. 2, 1927. Priority date: Sept. 4, 1926.

Process for filtering metals. British Maxium Ltd., Manchester, England. No. 69,030. Nov. 7, 1928. Priority date: Nov. 7, 1927.

Method of heat treating alloys, and alloys thus heat treated. M. G. Corson, Jackson Heights, N. Y. No. 69,031. Nov. 14, 1927.

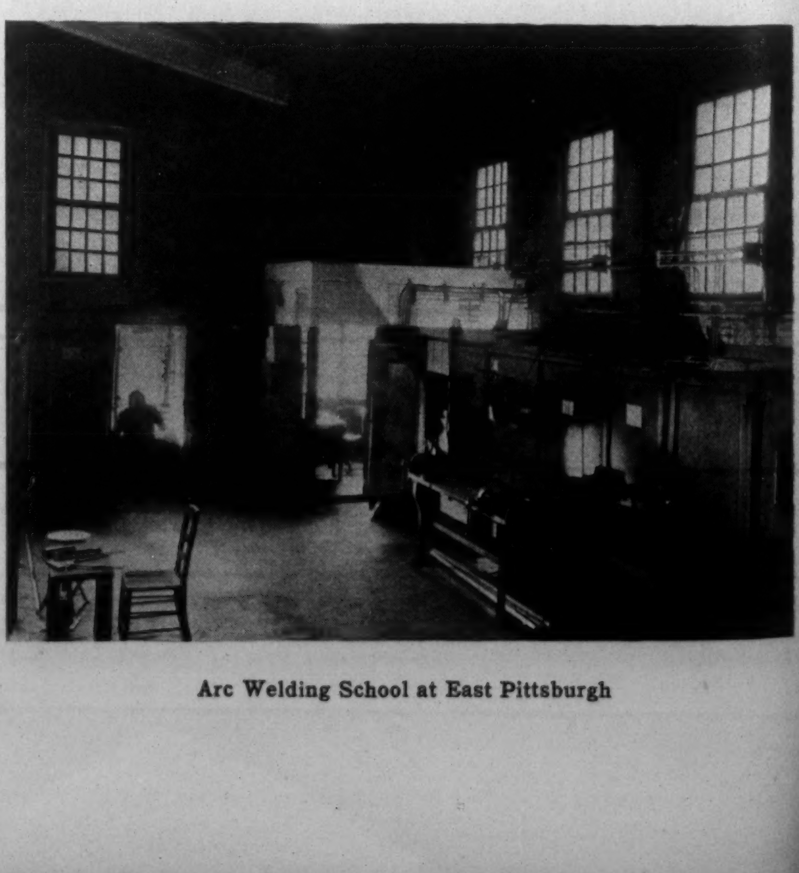
Process for the oxidizing roasting of copper chloride in roasted material. Reymersholms Gamla Industria AB., Hälsingborg, Sweden. No. 69,107. May 5, 1927.

Process for producing low-carbon metals and alloys. G. E. R. Nilson, Stockholm, Sweden. No. 69,108. Oct. 22, 1925.

Process for the electrodeposition of alloys. Standard Electric Aktieselskab, Oslo, Norway. No. 69,109. Nov. 22, 1927.

Arc Welding School

The photograph shows the especially equipped and constructed Arc Welding Schoolroom at the East Pittsburgh Works of the Westinghouse Electric and Manufacturing Company, where students receive instruction in arc welding. Each of the metal booths around the wall contains welding equipment for the student's use.



Arc Welding School at East Pittsburgh